POULTRY: FEEDS AND NUTRITION

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POULTRY: FEEDS AND NUTRITION

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Foreword

Agriculture is the world's biggest and most vital industry. The job of agriculture is to produce food to satisfy the nutritional requirements of the population. United States agriculture is the envy of most nations in the world. Of course, the United States is blessed with the land, animals, equipment, skill and the incentive to produce abundant food supplies efficiently. Industrialization of traditional agriculture production in the United States has resulted in all the food that is necessary for growing populations and a variety of nutritious foods at a price most people can pay. A small portion of disposable income is required for food. Agricultural scientists have worked diligently to give agriculture important tools in achieving new dimensions of efficiency. In contrast, Soviet farm output is 30% less than in the United States, even though their planted acreage is 75% greater and their farm labor force far outnumbers that of the United States.

The commercial feed industry and animal agriculture play unique roles in the U.S. economy. Millions of tons of animal feeds are produced annually by the commercial feed industry. This is a vital factor in the production efficiency of U.S. livestock and poultry producers. The United States could not have attained the abundant supply of high protein foods and the production efficiency of animal agriculture without the commercial feed industry. Animal agriculture's production is geared almost directly to consumer demand.

The world's livestock population is at least twice that of the human race. The food industry provides an inventory-free pipeline of abundant food production. It is founded on research that has developed an amazing variety of feed formulations to produce maximum efficiency in the production of meat, milk, and eggs. The commercial broiler industry that came of age in the mid 1940's is an excellent example of the feed industry's contribution to animal agriculture. Broilers used to require 5 lb of feed to gain 1 lb in weight and it took approximately 15 weeks for them to reach a 3-lb market weight. Today, broilers require half that amount of feed and time.

Properly processed soybean meal has given U.S. animal agriculture a foundation for production efficiency unmatched anywhere else in the world. This is indeed one of the most spectacular chapters in the story of modern civilization.

Animal foods are expensive compared to nonanimal foods and must be

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justified. Good crop land will produce 10 to 20 times the amount of human food that can be obtained by utilization of animals produced on the same area of land. At best, only a fourth of the protein in the edible parts of plants is returned as meat. A dairy cow is the most efficient converter (28%) and the beef cow the least efficient (6%) in converting plant protein into animal protein. The broiler, laying hen, and swine are intermediate with 22, 22, and 16% efficiencies, respectively. Alfalfa and soybean crops are the leading protein producers. High-protein cereal grains of the better balanced amino acid content, especially lysine, will have an impact on animal proteins and high-protein, oil-bearing seeds within the next decade.

Food resources are most limited in nations that are experiencing the greatest pressure from population expansion. Protein insufficiency is the prime culprit. Staples such as rice, corn, pulses, and cassava are so poor in protein that a child cannot eat enough to supply his protein needs. Proteins of animal origin such as poultry meat and eggs provide a concentrated source of readily assimilable amino acids in suitable proportions for human needs. Vegetable proteins most frequently available in developing nations do not convert into body protein as readily as animal protein. Kwashiorkor due to inadequate protein is common in Africa, Asia, and Latin America, whereas obesity is a major problem in North America and Western Europe.

If food of adequate quality is to be provided in a sufficient amount to meet the needs of the world's expanding human population, animal nutritionists must work closely with veterinarians, geneticists, and other animal specialists to apply present knowledge to the problem. From the global standpoint, we have the knowledge and skill necessary to achieve easily an enormously increased output of animal proteins. A most important aspect of solving this problem lies in the long-term aim of education. Great numbers of young people must be trained in the basic techniques of animal production and given advanced training in the fields of nutrition and disease control. Many outmoded traditional husbandry systems persist.

Worldwide, the food picture is not good. It is said that half of the people are hungry; two-thirds suffer from malnutrition. World population is growing twice as fast as world production. Undeveloped countries have both the greatest population increases and the need for food. The United States is committed to help fight world hunger but the feed-food situation in the United States is at a turning point. The joker in the world food situation is the ability to pay. If standards of economy in some of the ill-fed countries could be raised, the problem would be easier to solve. If the peoples of Latin America, Asia, and Africa had income from some sources, the food would be available. There is no place in the world that

has a food shortage if the money is there to pay for it. Religious taboos, need for land reform, social customs, lack of incentive and a host of other government and sociological problems are involved. The American system should be exportable.

A meat-eating economy is based on an affluent society, an overabundance of grain, a well-developed, sophisticated agriculture and strong purchasing power. Animal agriculture has certain limitations. Animals compete directly with man for his basic food supply, principally grains and high protein oil seeds. Animals are inefficient nutrient converters. More time and risk are involved in producing meat, milk, and eggs, and more skilled labor is required than for crop production.

Animal proteins have no magic exclusive nutritional values, just palatability. But the quality of the human diet is determined largely by the amounts of animal products consumed. Meat, milk, and eggs are especially important because they furnish high quality protein to balance the protein from vegetable sources. Many cereals and vegetables are too low in protein to meet the requirements of either adults or children and they are deficient in essential amino acids unless supplemented. Poultry meat is the richest source of protein per unit of energy, and eggs furnish liberal amounts of vitamin A, riboflavin, and iron. Many peoples of the world do not have supplies of these excellent foods because the conversion involves wastage of the total food supplies.

ED GLENNON, President
American Feed Manufacturers Association

Preface

From a source of the farmer's wife's pin money to a mass-produced, supermarket loss leader, poultry has made tremendous strides in the past half century. Paralleling its progress, and depending on it to a great extent, has been the feed manufacturing industry, two-thirds of whose volume is poultry feeds. It took a lot of doing, mainly by a team of scientists who ranged from nutritionists, geneticists, and biologists to pathologists, engineers and statisticians, to bring the U.S. poultry industry to its present efficiency. In the middle has been the poultryman trying to manage an enterprise that was growing nationally by leaps and bounds.

From expensive, New York-dressed, "chicken in the pot every Sunday," poultry has modernized to inexpensive, fully-dressed products that are marketed every day in the year, frozen or ready-to-eat. It has shown more progress than any other branch of animal agriculture.

In 1920, an average farm flock consisted of 200 hens or less; whereas today with advances in automation, the commercial poultryman may have 25,000 hens. Previous chores like mixing feed and housekeeping are done now by machinery so he can spend more time checking his chickens and trouble-shooting. Innovations in equipment and labor-saving devices developed by the poultry industry are being adopted by the livestock industry to a great extent.

Nevertheless, it takes more know-how and business acumen now to keep a poultry enterprise profitable. A poultryman must be more aware of other phases of the business. The more knowledgeable he is, the more likely he will survive in a very competitive business. Feed manufacturers must also be aware of the advances being made by poultry scientists so that their feeds measure up to the potential bred into modern birds. The amazing progress that has been made in recent years attests to the fact that communication between the groups is needed.

For many years there has been a need for greater application of the principles of nutrition to feeding practices as well as in preventing diseases of poultry. This treatise attempts to encompass the fields of poultry feeds and feeding in health and in disease in a concise and authoritative manner. It is hoped that it will help the nutritionist, veterinarian, and feeder to become more knowledgeable in the general area of poultry feeds and feeding and become a teaching aid for teachers and students of nutrition and feed technology, as well as for general poultrymen.

The solution of problems of nutritional improvement in poultry feeds

and feeding is vital to long-range betterment of standards for raising poultry and production of human food. Experienced feed formulators, feed manufacturers, county agents, vocational agricultural teachers recognize the necessity of using great care in the selection of feed ingredients for poultry. Nutrition principles explain the reasons why many established practices are very important in the formulation and mixing of feeds and provide the ways of assuring quality, uniformity, and the true value of manufactured feeds.

With nearly 80% of the world population needing an improved diet, any contribution toward producing more and better foodstuffs at lower cost is both worthwhile and timely. Feed and poultry production are not exact sciences but are based on knowledge, the base from which all progress is made. Critical phases of feed and poultry production, and current research are explored, and practical recommendations for meeting a variety of circumstances are made.

The U.S. Congress recently passed legislation authorizing the Bureau of Standards the possible adoption of the metric system. Half the world's population are now on the metric system. Canada and the United States are the only big countries still clinging to the fading imperial system. Britain hopes to have metrification completed by 1975. The simplicity and efficiency of the metric system is self-evident, its basis being the decimal point and the length of the meter. The latter is based on the wave-length of orange-red light given off by the element Krypton-86. The United States has had a legal metric system since 1866 which it does not use, while it uses the foot-pound system that has never been legalized. The benefits of a single measuring system are so great that conversion to the metric system is inevitable. Because of the international aspects of the book, measurements in the text are often given in both systems.

PHILIP J. SCHAIBLE

February 1969

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Contents

Introduction

Poultry nutrition deals with the laws governing the requirements of poultry for maintenance, growth, activity, and reproduction. Lavoisier in 1777 laid the foundation for the science of nutrition by supplying the basic facts regarding energy metabolism. Advances in physiology, and more especially the development of physiological chemistry in the last century, made possible efficient feeds and feeding. It is obvious that nutrition, feeds, and feeding are so closely interwoven as to be inseparable. Poultry assimilate feed for promoting growth, egg production, and replacing worn or injured tissues. Under the term *Nutrition*, the following are involved: digestion, absorption, metabolism, feed utilization, quantitative nutritive requirements, interrelationship of nutrients, etc. Under the subject of feeding are: composition and selection of feed, feed habits, feeds for all ages and conditions.

The Oxford English dictionary gave some ten different spellings of the word *diet* as it appeared in early English writings. It derives from the Latin *diaeta*, meaning mode of life. At first, it was used in the much broader sense than it is accepted today. It dealt with the doctrine of health and hygiene. This discussion will treat *diet* only as it relates to food and health.

For thousands of years, poultry ate anything that they could get. Not until the nineteenth century was it known that there was a difference in the dietetic value of different foods. *Ration* means a fixed allowance or allotment of feed in 24 hr or, more loosely, affixed portion or share of a feed. Roots, berries, fruits, and seeds were the first foods and later came honey, eggs, and fish of various kinds. It was not until the discovery of fire and cookery and the devising of weapons to kill animals that there was much use of animal foods. When man learned how to domesticate poultry, flesh and eggs became a part of his diet. He led a pastoral nomadic way of life with a necessity for frequent movement in search of new pastures. Man, the hunter, changed to man, the food gatherer. He learned to make tools so that he could crush seeds between stones to make meal and later, of course, flour for gruel, and then bread. By the time of Moses, fruits, seeds, herbs, bread, milk, fish, flesh, butter, honey, eggs, and cheese were man's diet and their waste products were used for feeding poultry. The early Egyptians, Greeks, and Romans cultivated food on farms, cooked their meat by boiling and roasting, and ate well. Storage or preservation of food was limited. Pickling, drying, salting, and smoking were early methods of

preservation. With the accidental discovery of the new world, Indian corn or maize added immeasurably to the food supply of man and poultry.

In sixteenth century Europe, meat and milk were still unusual foods but fresh, salted, and dried fish were common fare and vegetable growing was beginning to increase. By the seventeenth century, barley was in fairly general use. The invention of the steel-faced plow about 1840 led to the mass production of grain because the soil could be turned over to a depth sufficient to kill grass. The modern roller mill for breaking of the wheat grain and separation of bran, germ, and coarser grades of flour was developed about 1880. Since poultry was fed waste food from the human supply, their diets were more or less based on what was available.

The discovery of vitamins extends back through the years. Numerous observations indicated that some diseases could be prevented or cured by dietary changes. Although advanced knowledge in chemistry and analytic methods helped, it still required the development of a biologic technique using chickens, rats, guinea pigs, dogs, and other experimental animals to chart the way to identification of the essential food nutrients. There was considerable reluctance in the acceptance of dietary deficiencies as the explanation of disease because the work of Pasteur had finally been accepted and the infectious origin of disease was the dominant consideration.

A natural subsequent development in the matter of what foods poultry should eat, was the question "how much?" Quantitative studies advanced only with progress in chemistry, and thus little could be done in this area until the nineteenth century.

In simplest terms, poultry nutrition is concerned with what poultry need to eat in quantitative amounts of specific nutrients. This, of course, involves the "why" of the subject. Feeding is concerned with what poultry *do* eat in order to meet their specific needs and what they *should* eat in terms of individual variation, state of health, activity, and all the factors which influence selection of rations.

Markets for the Poultry and Feed Industries

Feed is needed to produce poultry, a substantial part of the food industry. The size of the food industry depends on population which is not constant. A tripling of the world's food supply will be necessary in the next 30 yr if 7 billion people in the year 2000 are to be adequately fed. The U.S. Dept. of Agr. estimates that the United States cannot continue to feed developing countries after 1984. If today's trends continue, there is likely to be further rapid deterioration in man's environment.

A fantastic world effort over the next decade at changing the attitude of people toward family size might conceivably arrest population at 2 or 3 times its present level. Some biologists feel that compulsory family regulation will be necessary to limit population. World population is exploding. More children are being born, many diseases have been cured, and the lifespan is increasing. It took from the beginning of time for world population to reach 3.3 billion; by 2000 A.D. that figure will more than double (Table 2.1).

TABLE 2.1

POPULATION PROJECTIONS: WORLD AND MAJOR AREAS—1965 AND 2000

World and Major Areas	1965	Population in Millions in Year 2000 on the Basis of Trends: Present	Medium	Low
World	3308	7410	5965	5296
Asia	1842	4401	3307	2969
East Asia	867	1803	1284	1114
South Asia	965	2598	2023	1855
Africa	311	860	768	684
Latin America	248	756	624	514
Europe	443	571	527	491
Northern America	215	388	354	294
Oceania	17	33	32	27
U.S.S.R.	234	402	353	316

Source Population Reference Bureau, Washington

The answer to the problem of feeding tomorrow's world is found in its agriculture and the men who grow food—farmers, feed manufacturers, livestockmen, and poultrymen. In the United States 1 farmer produces food for 40 people and thus frees the others to work at jobs on which the nation's progress depends. But agribusiness is more than one farmer feeding so many people. It is processors and distributors who make the food

available to the people. It is science providing new seeds, livestock strains, pest control, technical knowledge, and modern methods. It is educators teaching the young in the ways of agriculture. It is companies that make the hundreds of items farmers need. Food production has its roots deep in the farm.

Americans eat on the average 1,500 lb of food per year. The amount needed to feed Americans in 2000 A.D. is 135 million tons of food a year more than is being produced now.

Industries playing increasing roles in the struggle against world hunger include the poultry industry which requires less capital to enter than other animal industries, and the feed industry which provides economical feeds upon which the poultry industry depends. More than 96% of all food originates on land rather than from the seas.

FOOD CHAIN

Solar radiation energy is the driving force that keeps the earth's system going. Energy is captured by the food producers which may be simple algae in the water and rooted plants along the shore. All animals are predators either on other animals, plants, or both. Passage of materials from producer through primary, secondary, tertiary, quaternary, etc., consumers is called a "food chain." The end is generally an organism that is not preyed on by any larger form.

Each step along the food chain extracts only a fraction of the potential energy of the previous step. The food chain, thus involves a series of energy conversions; with each transformation from prey to predator along the food chain there is a loss of energy.

All organisms live in nature in a close and delicately controlled relationship with a great many other organisms forming a biotic community. It is said that the glory of England was due to its old maids. It is reasoned: "British men are nourished by roast beef; the cattle that supply the roast beef feed on clover; clover is pollinated by bumble bees; bumble bees nests are destroyed by field mice; and the number of field mice depends on the number of cats. Since old maids keep cats, their number ultimately determines how much roast beef is available." As far-fetched as this argument is, it nevertheless, emphasizes the important principle that in any biotic community the existence of each species, as well as each individual, is governed to some extent by the presence of all the others. Organisms depend on each other, directly or indirectly for day-to-day existence, but also compete for the resources available in the environment. This competition is mainly for energy to maintain itself and reproduce. A population of organisms with an unlimited food supply could quickly fill the entire earth with their own kind. The food supply of any population of organisms is

not unlimited. The growth rate of the population tends to outrun the growth rate of the food supply (Table 2.2). Thus, there is a continual struggle for existence among organisms and those that leave behind the greatest number of surviving fertile progeny are the most successful in the struggle for life.

TABLE 2.2

GLOBAL PRODUCTION OF MAJOR PLANT COMMODITIES[1]

Product	Weight	Dry Matter	Protein	% Global Intake
Wheat	250	212	19.5	32.0
Rice	260	222	16.0	27.7
Legumes	30	...	7.4	12.2
Potatoes	400	80	5.0	8.3
Corn	220	187	4.5	7.5
Other	253	157	7.7	12.3

[1]In million metric tons.

THE AMERICAN FOOD SUPPLY

The food manufacturing industry has experienced substantial growth in recent years. While a portion of this growth is attributable to increases in population and growing urbanization, a fundamental change has occurred in the buying habits and tastes of consumers due to rising per capita income. In earlier years, the housewife spent a great deal of her time processing ingredients from a relatively raw state to meals for the table. Today, a substantial part of the preparation of food is carried on by food manufacturers with the result that many products may be served with a minimum of preparation.

Each of us in the United States in 1965 consumed these products from the farm: 41 lb of chicken and turkey; 623 lb of dairy products; 167 lb of beef, veal, pork, lamb, and mutton; 175 lb of fruits (fresh fruit equivalent); 206 lb of vegetables; and 111 lb of white and sweet potatoes.

American agricultural abundance is helping to relieve hunger and to promote economic growth in the newly developing countries of the world. United States wheat provides an additional 13 billion loaves of bread a year for the people of India.

The U.S. food industry is (1) an $89,000,000,000 industry; (2) there are 6,000 food items on the shelves of supermarkets today; (3) the average person in the United States eats 1,500 lb of food per year; (4) there has been a 500% increase in low calorie foods in the last 5 yr; (5) every 5th meal is eaten outside the home.

In the United States, $67 billion a year is spent for food of which $31 billion goes to the chain stores. It is possible now to buy 3 times as much

food for an hour of work as in 1916, the year that the self-service idea was introduced. Last year per capita expenditures for food amounted $484.00, up $92.00 from 1960, but the spending as percentage of disposable income declined to 17½%.

HUNGER VERSUS MALNUTRITION

Malnutrition is a symptom of poverty caused by lagging economic development. Private industry has the opportunity to produce and market low-cost, high-protein foods which the poor can afford and accept. Children that survive a protein-deprived childhood cannot learn as well in their formative years as their well-fed counterparts. Their mental capacity, because of retarded brain growth, is permanently impaired.

Some nutritionists believe that alleged hunger in the United States is mainly a health problem that cannot be solved by simply putting more food in undernourished, empty bellies. They claim that reports are based on an emotional appeal and a political polemic rather than scientific judgment. Charges that nutritional anemia stem from protein and iron deficiencies in children from poverty background is challenged, because most of these children had intestinal parasites which may have been the cause of the anemia. Another childhood cause of anemia is overuse of milk, an iron, not a protein, deficiency. Thus, a major controversy is brewing over the extent of malnutrition and hunger in the United States.

POULTRY IN TOMORROW'S WORLD

A world now populated by 3.3 billion people maintains a livestock and poultry population equivalent to almost 15 billion human beings or a total feeding burden exceeding that of 18 billion human beings. The present world living mass (biomass) consists of 180 million metric tons of humans requiring 920 million metric tons of livestock and poultry for their food (Table 2.3). In other words, it takes about 5 times as much animal mass as that of man to satisfy man's need for food. Indirectly man is enjoying the support of a far greater biomass represented by the feed biochains of the oceans, freshwaters, and terrestrial wildlife, as well as soil organisms and a wealth of microorganisms.

Some have concluded that enormous quantities of food could be obtained if the level of agriculture were raised generally to that of representative countries in the world. They completely disregard the fact that these countries would be unable to manage as they do without importing considerable quantities of feed or without their fisheries.

Only 1/10 of what the human race eats consists of animal products. Meat, milk, eggs, and fish are by and large the privilege of a few hundred million people. Fish account for 2 to 3% of the total caloric consumption of man

TABLE 2.3

GLOBAL BIOMASS—HUMAN SPHERE IN PE[1] UNITS

		Area	Man	Poultry & Livestock	Total
			In Millions		
Cattle	8760	Asia	1.6	4.7	6.3
Man	3000	Europe	0.42	1.9	2.4
Hogs	1842	World	3.0	14.5	17.5
Sheep	988	U.S.S.R.	0.22	1.18	1.4
Buffalo	940	Africa	0.254	1.55	1.8
Horses	653	N. & Central America	0.262	2.03	2.3
Poultry	654	S. America	0.137	2.16	2.3
Goats	288	Oceania	0.014	0.446	0.46
Camels, Mules, Asses	375				

[1]Population equivalents.

and thus does not stand out as a particularly significant part of the daily diet. Comparisons between nations cannot be made entirely on an energy basis. A person cannot live on sugar and flour alone and remain healthy. More tons per acre are no more important than what kinds of tons are obtained.

An assumption is frequently made that each country is meeting the needs of its inhabitants. This is a fallacy. A number of countries have extensive undernourishment and nutritional deficiency.

Asia covers ⅓ of the land surface of the globe and comprises over ⅓ of the world's population. But it has only ¼ of the cultivated area and the world's available food. A mere 3% of India's diet consists of animal products and butterfat is a privilege of the rich. Only 500 million of the 3,300 million people of the world can afford a luxury diet—drink milk and eat beefsteak, pork chops, eggs, and poultry.

THE AGRICULTURAL ARMY

United States housewives, with the highest per capita income in the world, prefer animal foods because they taste good and provide nutrition for their families. Food is not thought of as an achievement in this country. When farming was a "way of life" in the early 1800's, the average U.S. farmer produced only enough food and fiber for himself and 8 other people. Now, it is a highly skilled profession demanding many special talents, particularly in the field of animal agriculture. Production of poultry, eggs, and meat must be increased another 25% by 1975 to meet expected increases in population.

Laying hens are efficient "factories" that use feed to turn out economical eggs. More efficient feeds and better egg "factories" permit U.S. citizens

to buy eggs economically. A Detroit housewife buys chicken that was hatched in New England, reared in Georgia, trucked to Michigan, packaged, displayed, and sold at the local supermarket. To feed this bird, soybeans were grown in Illinois, fish from the Grand Banks in the Atlantic Ocean were processed into fishmeal in New England, grains were grown in Indiana, phosphate was mined in the Caribbean, and vitamins were synthesized in New Jersey. These raw materials were purchased and combined by feed manufacturers to turn out economical and health-giving feeds for the bird.

Behind the poultry meat and egg producer is an agricultural "army" whose services are unsung. Land-Grant colleges and universities are constantly equipping agricultural manpower with the "why" and "how to" knowledge to produce more efficiently. Extension men carry the message to the farmers and assist them in putting the methods to good use. Veterinarians and entomologists devote their lives to fighting insects, parasites, and disease.

Pharmaceutical companies make important contributions from the standpoint of vitamins, hormones, antibiotics, and other medications. The nation's 3,300,000 farms, 300,000 retail food stores, and 13,000 food manufacturing plants make up the nation's largest industry which processes and distributes foods and employs 3,000,000 people.

American agriculture has advanced more in the past 50 yr than in all prior years. Modern farming combined with a progressive system of processing, marketing, and merchandising has provided abundant, wholesome food, when, where, and how we want it. Research is constantly improving plants and animals, finding new uses for farm products, and devising new and better methods of transporting, storing, and merchandising farm products.

The Poultry Industry

In 1967, U.S. poultry growers raised 2.5 billion broilers bringing total chick production to nearly 3 billion birds, up from 1.7 billion a decade earlier. Per person consumption of chicken and turkeys in the United States tripled from 15.7 lb per person in 1909 to 46 lb in 1967. Egg consumption per person declined from a peak of 380 eggs in the late 1940's to 324 in 1967. Egg production in 1967 was 5.8 billion dozen, up 5% from the previous year. Turkey growers raised a record 126 million birds providing 8.7 lb per person in 1967 in ready-to-cook weight. Chicken consumption per person was 37.5 lb in 1967. The consumption of poultry products is far from the saturation point (Table 3.1). Dietitians recommend an egg a day but rural people consume double that of city people.

According to the U.S. Dept. of Agr. there are some 3.1 million farmers in the United States. Actually, there are less than a million, if those grossing under $5,000 annually are not counted. The small farms account for only 8% of the total sales. Principals in animal agribusiness, particularly in the case of poultry and meat animals, actually number less than 100,000.

Over a billion and half chickens are hatched commercially each year for egg production; 4,400 million are hatched for commercial broilers and 500 million for farm chickens. Also, 110 million turkeys, and 310 million laying hens are produced. This production is spread over many hundreds of thousands of farms.

There is a general impression that poultry and egg production are carried out as large specialized commercial enterprises. In the past, this was not true but it is fast becoming the case. A decade ago, about 98% of the farms with poultry kept flocks of less than 400 birds. The picture has changed in recent years. Egg production is chiefly in the Midwest, the Northwestern States, and the West Coast. Commerical broilers are reared on the Eastern Shore of Delaware and Virginia (called the Delmarva Peninsula), Shenandoah Valley of Virginia, and the Southeast, as well as Arkansas, Texas, and California (Table 3.2).

The important areas of turkey production are in the Upper Midwest, Pacific Coast, and Middle Atlantic states. Flocks of over 10,000 turkeys are not uncommon, although the average size for commercial enterprises is around 2,000 birds. The production of ducks and geese is of considerably less importance, accounting for less than 1% of the total production of poultry. They are raised primarily in New York, Massachusetts, Pennsylvania, and California. Commercial table duckling production on a special-

TABLE 3.1

U.S. CIVILIAN PER CAPITA CONSUMPTION OF POULTRY, EGGS, AND RED MEATS[1]

Year	Eggs	Poultry, Ready-To-Cook Weights					Red Meats, Carcass Wt Equiv							
		Broilers	Chicken Other Than Broilers	Total Chicken	Turkey	Total Poultry	Beef and Veal	Pork Excluding Lard	Lamb and Mutton	Total Red Meats	Total Meat	Poultry as % of Total Meat	Broilers as % of Total Meat	Turkey as % of Total Meat
	No.	Lb	Lb	Lb	Lb	Lb	Lb	Lb	Lb	Lb	Lb			
1940	319	2.0	12.1	14.1	2.9	17.0	62 3	73.5	6.6	142	159	11	1	2
1950	389	8.7	11.9	20.6	4.1	24.7	71.4	69.2	4.0	145	170	14	5	2
1960	334	23.5	4.5	28 0	6.1	34.1	91.1	64.9	4.8	161	195	17	12	3
1967	326	33.4	4.1	37.5	8.8	46.3	109.2	61.0	3.7	174	220	21	15	4

[1]U.S Dept Agr., Econ Res Serv.

TABLE 3.2

FIRST TEN STATES IN EGG, BROILER AND TURKEY PRODUCTION, 1967

State	Eggs	State	Broilers	State	Turkeys
	Millions				
Calif.	8078	Ga.	447,123	Calif.	19,045
Iowa	3507	Ark.	365,371	Minn.	17,711
Ga.	4981	Ala.	324,629	Mo.	11,459
Penn.	3165	N. C.	262,872	Ark.	8337
Tex.	2943	Miss.	196,931	Tex.	8071
Miss.	2508	Md.	151,032	Iowa	7518
Minn.	2463	Tex.	161,434	N. C.	6922
N. C.	2949	Del.	127,346	Va.	5585
Ark.	3134	Me.	73,907	Wis.	5068
Ohio	2365	Calif.	69,045	Ind.	4320

ized scale is carried on chiefly on Long Island whose farmers raise more than 100,000 ducks annually. Geese comprise less than 0.2% of the total production of poultry and are raised on a very small percentage of farms, chiefly in the Midwest. Although on most farms, poultry are reared from six weeks to maturity outdoors, by far the largest proportion of the laying birds are kept indoors.

Egg production increased from 122 eggs per bird on a hen-housed basis in 1925 to 228 eggs in 1967. Spectacular progress is attributed to many factors, including improved strains, better breeding, more control of disease, and the increased use of commercially produced feeds.

TABLE 3.3

UNITED STATES POULTRY AND EGGS 1925–1965

Year	Avg No. per Yr Hens and Pullets (Million)	Eggs Produced (Billion)	Cash Receipts Poultry and Eggs (Million $)
1925	311	35	1,090
1935	276	34	811
1945	369	56	2,954
1955	309	59	3,178
1965	302	64	3,600

The U.S. poultry industry depends on the feed industry for much of its raw material and financial assistance to produce poultry meat and eggs. The feed and poultry industries may be miles apart geographically, but their dependence on each other is self-evident. Consequently, a general knowledge of each other's industries would make for better understanding and more efficient use of each other's products. Feed manufacturers should

know enough of the poultry industry to provide and manufacture proper and efficient feeds. Poultrymen should know enough about the feed industry to use their products to best advantage. Personnel from each industry can be knowledgeable in the practices of the other. As they learn, they will benefit both their own industries and the ultimate consumers.

In the science of poultry production, the scientific disciplines of nutrition, physiology, biochemistry, pathology, food technology, genetics, marketing, and management overlap, and all depend on each other. When large numbers of birds are to be raised to perform efficiently, the economic importance of different breeds and strains of birds is highlighted. Some breeds of birds need 6 to 7 lb of feed to produce 1 lb of meat. By selective breeding, birds capable of producing 1 lb of meat with less than 2 lb of feed have been developed.

THE CHICK AS A LABORATORY ANIMAL

The chicken has played important roles in nutrition research—more so than other animals because of its higher sensitivity to many dietary factors. In nutritional needs, humans are more like chickens than rats. Thousands of chicks are used each year to test products for fat-soluble and water-soluble vitamin activity. The chick is one of the most effective test animals for the antipernicious anemia factor for humans. The value of antibiotics and trace minerals was first discovered in the chick.

The chicken egg has contributed importantly to the culture of viruses that cause many human and animal diseases. Eggs are used for the production of many vaccines which produce a mild form of a certain disease, and stimulate the fermentation of a defense against the disease, thus providing an immunity. Eggs now stand between man and such universal and highly fatal epidemics as that of influenza, yellow fever, mumps, smallpox, fowl pox, rabies, psittacosis, encephalomyelitis, canine distemper, and polio. The conquest of many diseases has permitted most of those born to survive.

PRESENT STATE OF THE AMERICAN POULTRY INDUSTRIES

A third of all the poultry in the world is located in the United States. The United States uses a little more poultry products than it produces. Chickens constitute more than 90% of all poultry raised, the remainder being turkeys, ducks, and geese.

Among U.S. agricultural industries none has changed so profoundly in recent years as those of poultry and eggs. The American public demands convenience foods with built-in maid service because the housewife may work outside of the home. The live chicken at the corner market gave way to the New York-dressed bird and this, in turn, was replaced by the oven-ready product in the supermarket. Changes came in technology, organiza-

tion and location. United States farmers sold poultry and eggs valued at $3.5 billion in 1965, representing 9.1% of total cash farm income. Eggs accounted for half the value of farm poultry sales, broilers a third, turkeys 12%, and nonbroiler chickens the remainder. Consumers increased their intake of chicken and turkey meat substantially as advances in technology brought lower prices. Increasing production efficiency also brought lower egg prices, but preferences for eggs diminished rapidly. Even with lower prices, nearly ¼ fewer eggs were consumed in the mid-1960's than after World War II. Production of eggs has risen slightly, however, because of population growth.

Advances in poultry technology are illustrated in a commonly used measure of broiler production efficiency—the pounds of feed required to produce 1 lb of meat. For broilers, this ratio which was 4 in 1948 has dropped to around 2.2. The ratio for turkeys was 6.3 in 1948, and 4.2 in 1965. The pounds of feed required to produce 1 doz eggs decreased from 7.2 to an estimated 5.5. New developments in poultry nutrition, breeding, housing, and disease control all played a part, and were implemented by firms which gradually brought various phases of poultry production under one vertically coordinated management.

Changes in industry organization have resulted in shifts in principal production areas. The 5 top broiler producing states—Georgia, Arkansas, Alabama, North Carolina, and Mississippi turned out 60% of the total in 1965. The 2 major turkey producing states, California and Minnesota, accounted for 30% of the U.S. turkeys in 1965.

Egg production is more dispersed. In 1965, the 10 leading states produced half the nation's eggs. By comparison, the 10 largest broiler and turkey producing states accounted for 83 and 73%, respectively of 1965 production. The 5 states leading in broiler production produced 20% of the nation's eggs in 1965.

After World War II, producers could easily expand their poultry enterprises, provided they could obtain credit for feed. Feed manufacturers were willing to finance feed and were motivated to engage more extensively in poultry operations because this industry promised to grow rapidly. It offered an expanding market for feed without involving added selling costs. Feed manufacturers negotiated contracts which enabled growers to increase their output of poultry. The contracts provided for payment for the feed when the poultry was sold.

As feed manufacturers became more deeply involved in broiler production, they foresaw further advantages in owning their own hatcheries and controlling hatching egg supply flocks. Additional advantages were gained by combining processing with growing and thus marketing poultry meat rather than live broilers. As feed manufacturers increased processing

operations, fewer birds were available to specialized processors. To obtain regular supplies, processing firms entered into advance arrangements to obtain live birds from feed manufacturers and growers. The proportion of chickens grown under contract rose rapidly. The practice of contracting for the purchase of live birds decreased in relative importance. Feed manufacturers turned increasingly to contracting with growers to obtain their supplies. Broilers grown by the companies themselves account for a relatively small share of the total.

As contracting spread, there was a continuing *shift of management* and risk from the grower to the contractor. Major decisions increasingly were made by the contracting firm. Growers performed daily services under a broad management program established and supervised by the contractor. Growers furnished the land, buildings, equipment, water, electricity, and labor while contracting firms provided the other inputs. Most contracts had a base guarantee payment plus an incentive increment to encourage greater production efficiency. Some contracts allowed for the grower to share in market price of broilers.

Developing the basic breeding stock is a highly specialized business concentrated in the hands of a few leading firms. They continuously strive to improve their product through research and by keeping ancestors of superior performing broilers within their control. Products produced by these firms give superior performance and the quality of their product is maintained through genetic research.

Why was not ownership integration used instead of contracts? The answer is that many underemployed farmers with facilities were willing to sell their labor at very low rates because they had few alternatives. Contracts were attractive to integrators because they involved no social security, workman's compensation, and other similar employee costs.

Vertical coordination and control have not advanced as far in turkey as in broiler production. Turkeys need a longer growing period, and the market is seasonal. Also, capital and management requirements have been greater and disease risks higher. An estimated 60 to 70% of turkeys are grown under some type of arrangement between growers and other firms, or by firms owning both growing and other facilities.

Contracts to purchase grown turkeys rose in importance. The large meat packers with turkey operations turned toward advance arrangements for an increasing proportion of their live turkey needs. Four contract types are used: (1) marketing agreements, (2) minimum loss guarantee, (3) profit shares, and (4) flat payments.

During recent years, marked reductions in space requirements for growing birds have occurred. The biological goal in the laying hen is one 2-oz egg from each 2½-lb hen each day for 365 days on 3 lb of feed per dozen

eggs with less than 2% mortality during the laying year. In contrast, today's average hen lays 228 eggs in a year, weighs 4 lb, has a feed conversion of 4.4 lb per dozen eggs with yearly mortality losses of about 17%.

Through better breeding, feeding, and management, the average annual egg production has doubled during the past 50 yr (Table 3.4). The hen, the individual producing unit, has an average value of not over $2, but poultry and eggs concern more rural people, than any other phase of animal production. When the poultry industry is prosperous, many people benefit from it directly since the investment is small by comparison to many types of farming. It is easy to get in and out or to increase or decrease the number of chickens.

TABLE 3.4

FEED CONVERSION AND RATE OF LAY

Year	Eggs per Hen per Year	Feed Conversion (Lb Feed per Doz Eggs)
1925	122	7.5
1945	160	7.3
1950	183	7.0
1955	194	7.0
1960	210	6.6
1966	226	4.5
1967	228	4.4
1970 (est.)	230	4.0

The widespread distribution of poultry and egg operations means that marketing channels are greatly complicated. The egg is extremely delicate and sensitive to unfavorable surroundings. Of course, the egg was meant for reproducing the species, not for human food. It has its own ventilation system; tiny pores in the shell admit oxygen and permit escape of carbon dioxide and water, so that the embryo may live and grow. This is also true in infertile eggs marketed for human consumption. The industry tries to delay this process. Eggs are refrigerated to retard loss of water vapor through the shells and to aid in the maintenance of egg quality. Eggs are treated with mineral oil to provide a seal against the escape of water. Carbon dioxide is introduced into egg cases prior to shipment and into egg rooms in terminal warehouses in an attempt to reverse the normal process of transpiration. But there is no method for improving the quality of a poor egg. Commercial egg producers may live at distances up to several thousand miles from the final market.

In former years, eggs were produced on farms that specialized in other crops. Unfortunately for the egg, the corn farmer naturally thought of corn first. Today, however, more commercial poultrymen do just the opposite;

their living depends on keeping the hens in production and they think first of the chicken. Poultry were formerly dry picked and stored undrawn. Slack scalding and wax plucking have largely replaced previous methods and full drawn or other prepared poultry is marketed. Years ago, chickens were hatched under hens. Now, most chickens are purchased as baby chicks from commercial hatcherymen. The incubating of eggs and hatching of chickens has been taken off the farm and now is available almost as curb service. Accompanying commercial hatching is artificial brooding. For artificial brooding to succeed, it is necessary to provide adequate rations. Here the poultry and feed industries have made tremendous strides. Feed manufacturers now produce starting feeds which are vastly superior to those of years ago. When egg production is above the amount needed for fresh eggs for consumers, eggs are dried to use in bakery goods and institutional foods.

The poultry industry is more keenly aware of its responsibilities, its opportunities, and the problems than ever before. It was a major contributor to the nation's food supply during World War II. It learned how to increase production and reduce mortality with help from the drug industry. It has a continuing peacetime educational program designed to acquaint consumers with facts about the nutritional value of poultry products.

Changing practices in the poultry industry have sometimes been of great significance to the feed industry. Poultry and egg production occupies an important place in the agricultural economy of the United States, having grown in the last 50 yr from an incidental farm sideline to one of the principal agricultural industries accounting for approximately 12% of the total farm production. Egg production accounts for approximately 60% of the total value of the poultry industry, the remaining 40% being the marketing of chickens, broilers, turkeys, and other fowl. The productivity of layers has been rapidly improved in recent years by the adoption of better breeding, feeding, and management practices, and by the growing tendency to keep larger and more efficient flocks. Specialists display a marked efficiency of production by using scientifically balanced feeds, sound management practices, and labor-saving devices.

COMMERCIAL BROILERS

A very important division of the poultry industry is the commercial raising of broilers to a dressed weight of from 2½ to 3 lb at the age of 8 to 12 weeks. The growth of the broiler industry has been spectacular particularly in certain areas of the country (Table 3.5). This industry has been extensively developed in areas where the land is not suited for other agricultural purposes in North Carolina, Georgia, Arkansas, Texas, and California.

TABLE 3.5

U.S. BROILER MEAT PRODUCTION

Year	Age at Slaughter (Days)	Body Weight (Lb)	Feed Conversion Ratio (Feed to Meat)
1946	90	3	4.0
1956	68	3	2.8
1966	54	3	2.4
1967	53	3	2.2
1970 (est.)	50	3	2.0
1980 (est.)	45	3	1.7

Consumption of eggs and poultry meat in the United States has risen steadily in recent years. In its effort to support egg prices, the U.S. Government has been forced annually to buy large quantities of eggs which are dried and stored.

On most farms, pullets are reared from about 6 weeks of age to maturity out-of-doors, but by far the greatest proportion of the laying flock is kept indoors throughout the year due to climatic vagaries. Built-up litter systems, caged layers, etc. have been commonly adopted in many areas, although the use of batteries remains popular in California. Average egg production on the hen house basis increased from 92 eggs per bird in 1925 to 137 eggs in 1949, while the proportion of total output of eggs produced during the months of October, November, and December increased from 12.3 to 18.9%. This was chiefly due to the development of improved strains through selection and breeding, more careful control of disease, adoption of improved feeding methods, and the increasing practice of using commercially-hatched chicks. Important factors have been the higher proportion of pullets which comprise about 62% of all laying birds. In addition, there has been a general increase in the size of flocks. Despite this, the rate of pullet mortality is high, mostly due to various forms of lymphomatosis.

ADVANCES MADE POSSIBLE BY NUTRITIONAL RESEARCH

Efficiency of producing poultry meat has been spectacularly improved, due to more efficient rations than to any other single factor. Broiler specialists now produce a 3-lb bird in 10 weeks or less on 10 lb of feed. This is the result of research with a view to formulating cheaper, more efficient rations for all classes of poultry. Great advances have been made since 1905 when a textbook on poultry husbandry stated that the best combination for feeding young chickens was "a commercial johnny-cake, mixed with sour milk and soda to make it light." The first U.S. experiments on poultry nutrition were carried out at the Geneva Experiment Station in New York in the 1890's, and later at Cornell (Ithaca, New York), Wisconsin, and other centers.

The first really important results from nutritional research were realized about 1926 which revolutionized the rearing of chickens in the United States. This was the discovery of vitamin D, its presence in fish liver oils, and the value of these oils in preventing rickets in the absence of direct sunlight. Spectacular progress in poultry nutrition has been achieved through painstaking research carried on at the poultry nutrition departments at state colleges and laboratories of the larger chemical manufacturers.

Easy available credit has made possible the great commercialization of the poultry industry with its lower costs and margin. Tremendous scientific advances have reduced costs so sharply that it is going to be hard to match them in the future. Lower marketing and production costs have made poultry products more attractive to consumers and thus sales have expanded. Poultry products are now offered in areas where they were not formerly available on a year-round basis.

But the heyday of poultry expansion is drawing to a close and there is danger of overproduction. Future reductions in cost and improvements in efficiency of production will be at a much smaller rate than in the past. The Corn Belt States, the "egg basket" of America, are slowly being challenged on both the East and West Coasts and in the Deep South. Consequently, only modest increases in per capita consumption during the years ahead and a shift in production from the Midwest appear possible. The quality of shell egg packs will be improved and approach the high standards that the Pacific egg producers imposed upon themselves in the 1920's and 1930's when their eggs dominated the market.

The commercial broiler is currently the most efficient converter of feed to meat. Consumption of broilers has risen from 20.6 to 28.2 lb from 1950 to 1960, and the quality of chicken has improved. Turkey consumption has also accelerated due to lower prices through increased efficiency of growth.

TABLE 3.6

U.S. TURKEY MEAT PRODUCTION

Year	Age (Wk) Slaughter		Body Wt (Lb)		Feed Conversion	
	Toms	Hens	Toms	Hens	Toms	Hens
1952	32	32	25		4.5	5.5
1954	28	28	29	18	4.1	5.3
1958	[illegible]	24	30	17	4.0	5.1
1962	28	24	31	16	3.9	4.1
1964	28	24	32	17	3.7	3.7
1966	28	24	33	17	3.6	3.7
1970 (est)	25	21	31	17	3.2	3.4

SOURCE OF POULTRY AND FEED INFORMATION

Those who work in nutrition should be in touch with what is going on around the world in research. Some sources of information are as follows: U.S. Dept. of Agr. publications on animal and feed production, and Bureau of Commercial Fisheries publications on fish meal. Publications by drug manufacturers tell how drugs are used in feeds to combat various diseases. Ingredient suppliers provide tables giving amounts of nutrients that feedstuffs contribute. The Feed Bag Red Book (a monthly journal) publishes the names and addresses of producers and suppliers of feedstuffs, and has much useful information on where to find what poultry feed.

FIG. 3.1. NUTRITION JOURNALS WHICH CONTAIN SCIENTIFIC ARTICLES ON POULTRY NUTRITION

The feed industry has national, state, and community manufacturers. One of the largest national manufacturers puts out news bulletins on nutrition with much scientific and practical information on poultry raising. The Dehydrators Association has similar material and an abstract service on the components of dehydrated alfalfa. The Dehydrators Association

publishes the minimal values that will be available in all of the ingredients put out by the hundreds of companies in their association. The alfalfa people go into nutrition rather extensively with brochures on the cutting and harvesting of alfalfa and many other items. The publications save much time for the research worker.

Drug companies put out extensive publications reviewing experimental work on their feed additives. Feed ingredient companies distribute publications covering research and development in feeds that they market. Their purpose is to acquaint nutritionists with their products which can be added conveniently to local feeds. This type of material is not in any textbook.

FIG 3.2. U.S MAGAZINES WHICH INFORM THE FEED INDUSTRY OF MATTERS CONCERNING FEED MANUFACTURE

The following list of books, technical journals, and trade publications contain much valuable information on the nutrition and practical feeding of poultry. Some are technical, others semipopular. Some books are on general nutrition; others specifically poultry nutrition.

Sources of General and Poultry Nutrition Information

EWING, W. R. 1951. Poultry Nutrition, 4th Edition, W. Ray Ewing Publisher, P. O. Box 248, South Pasadena, Calif.

HEUSER, G. F. 1955. Feeding Poultry, 2nd Edition. John Wiley & Sons, New York.

MAYNARD, A. 1951. Animal Nutrition, 3rd Edition. McGraw-Hill Book Co., New York.

MORGAN, J. T., and LEWIS, D. 1962. Nutrition of pigs and poultry. Proc. Univ. of Nottingham, 8th Easter School Agr. Sci., Butterworths, London.

MORRISON, F. B. 1948. Feeds and Feeding. Morrison Publishing Co., Clinton, Iowa.

SHERWOOD, R. M. 1951. The Feed Mixers' Handbook. The Interstate Publishers, Danville, Ill.

TITUS, H. W. 1949. The Scientific Feeding of Chickens. The Interstate Publishers, Danville, Ill.

U.S. DEPT. OF AGR. 1962. After a Hundred Years, Yearbook Agr. U.S. Govt. Printing Office, Washington, D. C.

WHERRY, L. 1947. The Golden Anniversary of Scientific Feeding. Business Press, Milwaukee, Wis.

WINTER, A. R., and FUNK, E. M. 1941. Poultry Science and Practice. J. B. Lippincott Co., Chicago.

FIG. 3.3. POULTRY MAGAZINES THAT CARRY POPULAR ARTICLES ON POULTRY AND FEEDS AND FEEDING

List of Trade and Technical Journals

Biochemical Journal, Cambridge University Press, 32 E. 57th St., New York.
Feed Age, 71 Vanderbilt Ave., New York
Feedstuffs, Box 67, Minneapolis, Minn.
Journal of Biological Chemistry, 428 E. Preston St., Baltimore, Md.
Nutrition Reviews, The Nutrition Foundation, 99 Park Ave., New York.
Poultry Science, Poultry Science Association, College Station, Texas.
Poultry Digest, Garden State Publishing Co., Garden State Bldg., Sea Isle City, N J
Poultry Tribune, Mt. Morris, Ill.
The Feed Bag, 1712 W. St. Paul Ave., Milwaukee, Wis.
Western Feed and Seed, 320 Market St., San Francisco, Calif.

The Feed Industry

The feed industry differs significantly from other major farm supply industries in that most of its raw material is farm produced. In addition a considerable part of this feed is consumed on farms where it is produced. The portion of the feed manufactured in separate, nonfarm industry has been growing in volume. Mixed feed production by type for important countries of the world is given in Table 4.1.

TABLE 4.1

MIXED FEEDS[1]: PRODUCTION BY TYPE IN SELECTED COUNTRIES, 1965

Country	Poultry	Cattle	Swine	Other	Total
			(In 1000 M.T.)		
Canada	2077	1633	1521	41	5272
Mexico	874	145	71	3	1093
United States	27,600	15,900	8000	1600	53,100
Argentina	840	96	216	48	1200
Colombia	217	55	11	4	287
Venezuela	307	71	60	8	446
Belgium	753	716	944	65	2478
France	1870	973	1403	306	4552
Germany, West	2815	1747	1864	184	6610
Italy	960	500	500	40	2000
Luxembourg	12	16	21	...	49
Netherlands	1725	1625	2200	75	5625
Denmark	656	1038	1577	6	3277
Ireland	133	87	575	9	804
Norway	191	346	258	21	816
Sweden	357	34	446	11	848
United Kingdom	4095	3377	2253	173	9898
Israel	405	245	...	80	730
Japan	5033	845	1587	59	7524
Philippines	156	...	50	1	207
Australia	715	n.a.	n.a.	239	954
South Africa	445	194	42	7	688
Total	52,236	29,643	23,599	2,980	108,458

[1] "Mixed feeds" include both complete feeds and high protein concentrate mixtures to which grain must be added to make a complete, balanced feed.

THE AMERICAN FEED INDUSTRY

Consumption of feed by livestock and poultry in the United States increased about 37% from 1940 to 1966. The demand for formula feeds is derived from the demand for livestock and poultry products. Consumption of poultry meat per capita has increased steadily in the last 3 decades and now amounts to nearly 20% of the total per capita meat consumption.

Per capita consumption of eggs and dairy products as a group has declined. These shifts in consumer preferences have a decided impact upon the feed industry. Much of the production of poultry is coordinated closely with hatcheries, poultry processing firms, and regionally and nationally identified feed companies. Nearly all broilers are produced under some integrated or contractual arrangement. Ninety percent of the turkeys are fed under some form of extended credit programs sponsored or backed by a feed or processing company.

The feed industry plays an important role in poultry production. It attains a major share of its income from the poultry industry. The fortunes of the feed man rise or fall with the fortunes of the poultryman. In the past, the feed industry had the mistaken idea that universities injured the formula feed business by publishing formulas for starting, growing, laying, and breeding mashes. Keeping the public informed actually serves in the long run to benefit the feed industry. Informed feeders come to the conclusion that it is not a simple matter to combine various feed ingredients to produce an efficient starter or laying mash. They are then confronted with the decision as to whether they would rather spend less time as a poultryman or leave this to a feed concern that buys tested ingredients in carload lots at less cost. They would probably come to the conclusion that their time would be more advantageously utilized in doing a better quality job with the animals or that they could expand the size of their poultry operations.

The feed industry has many problems constantly arising which they do not have the facilities to properly study. In many cases, it is less expensive for the feed companies to farm out such problems to universities to investigate. Companies execute a memorandum of understanding with the universities with a specific understanding that research work will be carried on in a given area of primary concern to the donor and the university. It is frequently more feasible to place a given amount of money at an institute that is working in that particular area, rather than to broaden the company's own research program. This is particularly true if the research can be expedited by the use of expensive technical equipment which the universities already have. The university carries the overhead and supervision and the scientists working on the problems have the benefit of the libraries, laboratories, and other facilities, as well as consultation with other staff specialists.

Prepared feed as a proportion of total animal feeds has risen significantly because improvements in feeds have made them more economical per pound of meat produced (Table 4.1A). Properly processed soybeans, for example, have many times the protein value of raw, chopped beans. In addition, growing sophistication in business management among feed-

TABLE 4.1A

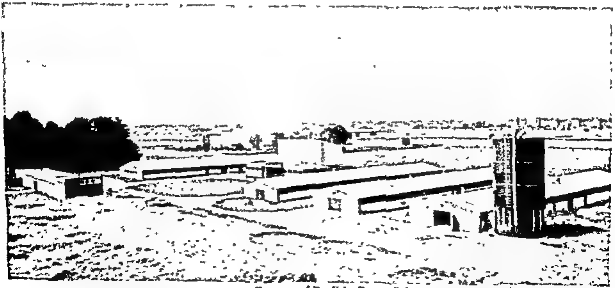
PERCENTAGE OF COMMERCIAL FORMULA FEED PRODUCED BY FEED MANUFACTURERS AS COMPLETE FEED[1], BY CLASS OF FEED, 1960–1965

Class of Feed	Complete Feed as a Percentage of Commercial Formula Feed			
	1960	1962	1964	1965
Broiler	81	83	88	91
Starter-grower egg-type	90	85	87	89
Turkey	79	70	77	81
Layer-breeder egg-type	73	72	74	76
Dairy	77	73	74	74
Hog	31	29	26	29
Beef and sheep	31	29	26	27
Miscellaneous	93	88	89	91
Total	68	64	64	66

[1]Commercial formula feed was divided into two groups for this report:
(a) Complete—feeds which do not require additional grain, and
(b) Supplements—feeds which should be mixed with grain or fed with grain. Therefore, subtract the complete feed percentages as indicated in the table above from 100% to determine the percentages which were supplements.
Source: AFMA Feed Tonnage Reporting Service

ers has led to greater appreciation of utilization of time and labor of the feeder.

Nutrition research was responsible for the development of formula feeds that changed the industry from small units concerned with moving surplus grains to deficit areas and marketing the by-product feeds of the milling industry. The feed industry provides a growing market for minerals, vitamins, antibiotics, and other microingredients now used in mixed feeds. Two-thirds of all concentrates moving to commercial channels are in



Courtesy of Dr Fritz Bauer, Fabwerke Hoechst Ag, Frankfurt, Germany

FIG. 4.1. LARGE FEED MANUFACTURERS HAVE EXPERIMENTAL FACILITIES FOR EVALUATING THEIR FEED FORMULATIONS AND TESTING NEW PRODUCTS

formula feeds or mixed concentrate feeds. The growth of the industry has been especially rapid since 1939. Value of shipments of prepared animal feeds was nearly 10 times as much in 1963 as 1939, although the number of firms increased only slightly.

Automation and innovation have been responsible for much of the growth and efficiency. There has been an increased emphasis on feeding poultry south and west of the Corn Belt which has encouraged more feed manufacturing in these areas. There is a trend toward decentralization of feed manufacturing plants. Mainly responsible have been demands for bulk feed services, changes in transportation costs, and growth of demand in new areas. The structure of the industry is shifting away from the elevator and flour business to vertically integrated firms. By 1964, the 4 largest firms had 17% of industry sales, and the 20 largest had slightly less than 31% of the total reported sales of manufactured feeds. Some feed companies retain terminal market locations, yet recognize the need for decentralization. The neighborhood mill serving specialized types of farming is common in the industry. Some firms emphasize mixing and sale of complete feeds; others specialize in supplements and concentrates. Feed depots and satellite mills are now being tried throughout the industry.

Farmer cooperatives have made important contributions to the feed industry. They handle about 20% of the commercial formula feed business in the United States. To qualify for direct mill procurement, farmers must use a large volume of feed. To offset this potential loss of business, many retailers provide added services.

EUROPEAN USAGE OF FEED

The total tonnage used in Europe was 33.9 million tons in 1966. Thirteen million tons, or 39%, were used for poultry. In general, poultry use of formula feeds leads the list and averages from 24 to 46% of the total feed tonnage. Swine comes next with from 19 to 46%. More poultry feed than swine feed is produced because the two big overall feed producers are Germany and Great Britain.

UNITED STATES FEED USAGE

The feed industry is the tenth largest industry in the United States because poultry meat and eggs occupy an important place in its economy. It grew in the past 50 yr from the sideline to a large enterprise, representing approximately 12% of the total farm production. It is fifth in importance of the various phases of agriculture, exceeded only by cattle, feed grains, dairy products, and pigs. Fifty-seven percent of this feed is manufactured

TABLE 4.2

CLASSIFICATION OF FEED MANUFACTURED BY MEMBERS OF AFMA

	Percentage of Total		
Classes of Feed	1955	1965	Largest Changes
Egg-type feed	32	27	x
Dairy	17	19	—
Broiler	20	16	—
Swine	11	16	x
Beef and sheep	8	12	x
Turkey	5	4	—
Miscellaneous	6	6	—
Total	100	100	

Source: AFMA Feed Tonnage Reporting Service.

for poultry or nearly three times that for dairy feed. Of the poultry feed, 64% is fed to laying birds, 28% to broilers, and 8% to turkeys.

FEED MANUFACTURERS ASSOCIATIONS

The feed industry has organizations on national, regional, and state levels. In Chicago, near the Grain Exchange, is the headquarters of the American Feed Manufacturers Association (AFMA). One of its committees composed of economists from different universities does feed surveys in cooperation with the National Turkey Federation. The committee determines what will be the needs of the livestock industry for various feeds for the coming year. Whether livestock numbers are expected to increase or decrease is important to feed companies because they have to purchase products months in advance of manufacture.

The American Feed Manufacturers Association has grown into a trade association of great importance, representing over 700 feed manufacturers and allied businesses throughout the United States and several foreign countries. Northeastern Feed Manufacturers Association was formed in the late 1920's. The Southern Mixed Feed Manufacturers Association got its start during the 1920's and was active until 1941. The Midwest Feed Manufacturers Association was first organized in 1930 in Kansas City, Mo., and the Northwest Feed Manufacturers Association in 1937 with headquarters in Minneapolis, Minnesota.

Since it was founded, AFMA has expanded its activities to cover the important needs of feed manufacturers. Committees have been organized as follows: Feed Control Relations, Industry Advisory, Feed Market Survey, Legislative Market Research, Additives, Public Relations, Purchasing Agents, Traffic, Nutrition Council and *Sales Executives. (Infor-*

TABLE 4.3

BULK VERSUS BAGGED, COMMERCIAL FORMULA FEED PRODUCTION, 1960-1965

Region	Percentage Bulk			
	1960	1962	1964	1965
South Atlantic	57	65	71	76
East South Central	55	65	65	71
Pacific	60	69	64	68
Mountain	32	43	59	61
West South Central	41	48	52	57
New England	31	47	50	56
Mid-Atlantic	32	44	49	55
East North Central	20	26	33	37
West North Central	25	28	32	36
U. S. Total	[illegible]	46	50	55

Source: AFMA Feed Tonnage Reporting Service

TABLE 4.4

PERCENTAGE OF COMMERCIAL FORMULA FEED PRODUCED BY FEED MANUFACTURERS AS COMPLETE FEED BY REGION

Region	Complete Feed as a Percentage of Commercial Formula Feed		
	1960	1964	1968
New England	[illegible]	98	99
Pacific	92	93	96
South Atlantic	84	86	88
Mid-Atlantic	83	87	83
East South Central	71	74	81
West South Central	78	74	78
Mountain	62	51	44
East North Central	41	37	35
West North Central	42	31	34
U. S. Total	68	64	66

Source: AFMA Feed Tonnage Reporting Service

mation collected and furnished their members is shown in Tables 4.2, 4.3, and 4.4.)

PRESENT IMPORTANCE OF THE FEED INDUSTRY

The U.S. feed industry now produces 40 million tons of feed annually, valued at more than 3 billion dollars. Nearly all feed manufacturers offer complete and concentrate feeds; a few offer premixes. During the early years, the basic feeds were complete feeds ready for feeding. Concentrates containing protein, trace minerals, and vitamins for mixing with the farmer's grain were introduced in the late 1920's. This feed was ideally suited for the grain-producing areas. While some manufacturers pushed the sale of concentrates, others were reluctant to lose the manufacturing

volume built up through the sale of complete feeds, and to turn responsibility for mixing the grain and concentrate over to retail feed dealers.

The size and efficiency of poultry production today in comparison with pre-World War II period is stupendous. Who would have dreamed in 1900 at the beginning of the U.S. feed industry of producing birds weighing 3 to 3½ lb in 8 weeks with less than 10 lb of feed per bird? To illustrate what such performances mean nutritionally, take calcium—a good domestic hen lays in a year 250 eggs containing 1¼ lb of calcium, 20 times the amount of calcium in the hen's body. A large proportion of the calcium passes through stores in the bones of the hens. In contrast, a cow in lactation 300 days would put out in her milk only twice as much calcium as she has in her body. This impressive performance of birds is not due to improvement in nutrition alone. But the fact remains that diets of today must be vastly superior to those of 10 or 20 yr ago to have allowed such improved performance.

COMMISSION MERCHANT

The grain commission merchant seeks the highest price obtainable for grain products offered for sale through him. He provides the finances upon which the small grain handler or elevator man at the county level can depend. The Grain and Feed Dealers Association, 725 15th Street, N.W., Washington, D. C. is an association of elevator and feed manufacturers who prepare animal feeds. Grain elevators are its largest activity. In 1953, there were 8,286 grain elevators of the following classifications: 33 terminal elevators receiving most of the grain by rail, 2,915 cooperative elevators, 2,572 independent (1 elevator), 2,156 line (more than 1 elevator), 7,600 reported bin space, totaling roughly 3 billion bushels. There are about 10,000 grain elevators under the uniform grain storage agreement of the U.S. Dept. of Agr. and about 12,000 feed plants under Food and Drug Administration regulation.

THE IMPORTANCE OF COMMISSION HOUSES

The commission house has an important role to play in grain marketing. About 1885, the railroads expanded west from Minneapolis and made it impossible for farmers to deliver or sell their grains direct to the mills and other terminal industries. It became necessary to build in the area in which the grain was grown. Commission merchants organized farmers' elevators and assisted them in building and financing these along the lines of the northern railroads. The commission merchants loaned the elevators the money to build, and for the purchase of grain, as well as for operations. In return, the local elevator hired the commission man as its terminal representative to handle his affairs in the terminal market. Com-

mission houses provide delivery to the terminal market. Commission companies maintain separate inspection departments in which all grain consigned to the company by country elevators is checked against the official inspection.

The local elevator looks to the commission merchant for financing, marketing information, and representation on the grain exchange. It guarantees to the producer a cash market for his grain.

THE IMPORTANCE OF THE FEED INDUSTRY TO THE FOOD INDUSTRY

In this day and age, the feed and food industries are inseparable. Seventy percent more farm commodities are now produced on 10% fewer acres. The feedmen's customers are becoming fewer, larger, smarter, and more demanding. One of the main responsibilities of the feed industry is the broadening of its ability to assist the producer in all aspects of production and in the complicated business of marketing the end products. Feed companies are now involved in egg marketing and processing plants. The feed man must be interested not only in feed but in foods. He must be interested not only in nutritional developments that allow animals to grow faster and more economically, but also in the housewives' preferences for all kinds of animal products. The feed industry is uniquely capable of relating consumer preferences back to the point of origin, the poultry house and the feedlot. The feed man today is essentially a food man and should be regarded in this feed-food context.

It is a pretty safe assumption that poultry and red meats will continue to be preferred in this country for as long as we can foresee in the future. With consumers becoming more affluent all the time, a vastly expanding market for poultry products seems assured.

SOME TRADE ASSOCIATIONS AND GOVERNMENT AGENCIES CONCERNED WITH FEEDS FOR POULTRY.

Trade Associations

American Feed Manufacturers Assoc.
53 W. Jackson Blvd.
Chicago, Ill.

Grain and Feed Dealers National Assoc.
500 Folger Bldg.
725 15th St., N.W.
Washington, D.C.

American Meat Institute
59 East Van Buren St.
Chicago, Ill.

American Dehydrators Assoc.
Kansas City, Mo.

Brewers Yeast Council
670 N. Michigan Ave.
Chicago, Ill.

Distillers Feed Research Council
1435 Enquirer Bldg.
Cincinnati, Ohio

National Fishmeal and Oil Assoc.
Washington, D. C.

National Assoc. of Retail Grocers
360 N. Michigan Ave.
Chicago, Ill.

National Canners Assoc.
1133 20th St., N.W.
Washington, D. C.

National Institute of Animal Agriculture
Purdue University
Lafayette, Ind.

National Renderers Assoc.
Des Plaines, Ill.

National Livestock and Meat Board
36 S. Wabash Ave.
Chicago, Ill.

Soybean Nutritional Research Council
3818 Board of Trade Bldg.
Chicago, Ill.

Scientific and Technical Societies

American Public Health Assoc.
1790 Broadway
New York, N. Y.

Institute of Food Technologists
221 N. LaSalle St.
Chicago, Ill.

Poultry Science Assoc.
C. B. Ryan, Sec.-Treas.
Texas A & M University
College Station, Texas

Institute of Nutrition
Wistar Institute of Anatomy and Biology
36th Street at Spruce
Philadelphia, Pa.

U. S. Government Agencies

Food and Drug Administration
U.S. Dept. of Health, Education and Welfare
Washington, D. C.

Federal Trade Commission
Pennsylvania Ave. at 6th St., N.W.
Washington, D. C.

U.S. Public Health Service
U.S. Dept. of Health, Education and Welfare
Washington, D. C.

Poultry and Feed Supplies Around the World

Dramatic new, high-yielding varieties of food grains are being disseminated around the world and yields are proving better than was first thought possible. Nevertheless, food production of the less developed countries has scarcely kept pace with population growth. Food is no longer a free commodity; it is exchanged for certain commitments, primarily to improve agriculture. Feed production figures in various countries are given in Table 5.1.

Exciting new varieties of rice, wheat, grain, sorghum, and corn developed at the International Rice Institute in the Philippines and the International Maize Improvement Center in Mexico and in the United States are now available. These out-yield traditional varieties and are much more responsive to fertilizer.

The Philippines expect to be self-sufficient in rice in a year or so, and Turkey, in wheat shortly thereafter. Food quality is also being improved through the development and utilization of low-cost sources of protein. It is now economically feasible to upgrade cereal protein by adding small quantities of a limiting amino acid. Four pounds of lysine costing $4.00 in a ton of wheat raises the quality of protein to a level approaching that of casein. Asian agriculture is gradually being placed on a more modern footing permitting a pattern of self-sustaining agricultural growth.

FEEDING EXPANDING POPULATIONS

A significant percentage of the population in developed countries eats well, indeed overeats, but this is an exception to the general pattern. In the less-developed countries, food production gains have been offset by population growth.

Experts in poultry science and feed manufacturing can be of considerable assistance in this regard. Particularly, there is a need for agriculture based on animals to supply protein for the diet. Since poultry production is relatively easy to get into and provides a market for feed manufacturers, the combination of these skills should help considerably. Perhaps all that is needed, in some cases, is a plant to manufacture foolproof feeds.

The Importance of Poultry on Feeding the World

How will we feed the expanding world population? Poultry is perhaps more important to human welfare today than ever before in history. Poultry products are dependable sources of life supporting nutrients. With

TABLE 5.1

ESTIMATED WORLD PRODUCTION OF SELECTED AGRICULTURAL COMMODITIES, 1967

Commodity	Metric Tons	1967
Wheat	Mil.	277
Rye	Mil.	32
Rice, rough	Mil.	262
Corn	Mil.	227
Barley	Mil.	98
Oats	Mil.	43
Sorghum and millet	Mil.	43
Sugar, centrifugal	Mil.	65.8
Sugar, noncentrifugal	Mil.	8.0
Fruits, citrus	Mil.	20.7
Potatoes	Mil.	240
Dry beans	1000	5621
Dry peas	1000	1369
Soybeans	Mil.	36.3
Peanuts	Mil.	18.4
Cottonseed	Mil.	21.2
Flaxseed	1000	2562
Sesame seed	1000	1463
Castor beans	1000	680
Sunflower seed	1000	8775
Cocoa beans	1000	1288
Rapeseed	1000	4621
Olive oil	1000	1235
Palm oil	1000	1179
Palm kernel oil	1000	318
Coconut oil	1000	2200
Tallow and greases	1000	4173
Lard	1000	3647
Milk	Mil.	313
Red meats	Mil.	57.0

a trend in animal agriculture towards bigger and fewer production units, feeding operations are being located nearer processing installations and consumers. Larger feeding operations and use of automation make complete manufactured feeds desirable. Feed manufacturers are in a more favorable position to serve large feeders. Many other factors besides ingredient cost make up the cost of a manufactured feed. Qualified nutritionists are needed to develop the feed formulas. Nutritional judgment must direct electronic calculations—mere arithmetic is not enough. Formula feeds are made largely from by-products of other industries and grain products, and a wide variety of feed additives. Chemical, microbial or enzyme ingredients are used to increase nutritional value.

Rice, corn, wheat, soybeans, chick peas, and certain oil seeds which make up a large share of the diet of the world's population are inexpensive but lack certain essential amino acids. These foods can be balanced with proteins and improve the diet of the world. However, for religious and

esthetic reasons, a massive program will be necessary to accept animal foods. Thirty grams of animal protein per day will provide all the protein required to maintain the human body in vigorous health. The highly productive North American continent cannot continue to feed the world. The answer lies in strengthening the economy of the less developed nations so they can feed themselves.

Two-thirds of the world's population now live in countries that are nutritionally deficient, where the daily diet averages 300 Cal less than the 2,300 Cal considered desirable and their daily consumption of protein is less than ⅔ of that in diet-adequate countries.

The U.S. feed and poultry industries can help participate in closing the food gap. Their contribution of vitamins, drugs, hormones, antibiotics, etc., can accelerate the conversion of feed to food. United States scientists can make most important contributions from the vast reservoir of knowledge and technical skills developed over the years. The application of this special knowledge and technology in the underdeveloped nations in the world should prove to be beneficial to all involved.

The Importance of Rice

More than half the world relies for their basic food supply on the tropical rice plant which literally falls down on the job. If the rice plant is to feed more than half of the 5 billion people who will be on the earth in 20 yr time, a dramatic change in its structure is essential. The development of short-stemmed rice varieties that will not fall over when fertilized, yet give high yields and resist disease are now being undertaken by the International Rice Institute in the Philippines. Such new varieties are making a substantial impact on rice production. Research on problems of this kind has long been recognized in the United States. A network of agricultural research stations is a major component of a highly developed farming industry.

American Foundations work outside their country's border to advance human welfare. The Ford Foundation which conducts the largest foundation program overseas spends \$50 million annually. These enable skilled consultants to train personnel many countries need for their development. The U.S. Agency for International Development spends abroad annually more than \$2 billion.

FAR EAST

Japan

The ruggedly mountainous country of Japan is feeding itself better than ever before. Productivity per acre is probably the world's highest. The rice

supply now exceeds the nation's requirement by 10%. Rice now accounts for 45% of the Japanese farm production and is the only food item subject to the control system instituted in 1945 to encourage production. The government now has about 2.6 million metric tons of stockpiled rice.

Japan's farms are too small for truly economic operation. As the Japanese diet has become more diversified, there has been a greater consumption of meat, eggs, vegetables, fruits, and bread. Japan's heavy food imports make her the second biggest foreign customer of the United States.

India

This country has struggled for generations to feed its people against appalling odds. Lack of new land, primitive farming methods, unpredictable climate, and religious taboos combine with rising population in already overcrowded cities to make uncertain even a substandard diet (Table 5.2).

TABLE 5.2

FOOD GRAIN PRODUCTION IN INDIA

Grain	1966–1967
	(1000 Metric tons)
Wheat	11,528
Barley	2449
Corn	4991
Sorghum	8944
Spiked millet	4503
Raggee	1600
Small millets	1671
Rice, milled	30,441
Total	66,127
Chick peas	3612
Pigeonpeas	1731
Other pulses	3579
Grand Total	75,049

A monsoon climate with 3 to 4 months wet and 8 to 9 dry months a year results in one of the world's lowest crop yields per acre. India has far more cattle than she can properly feed or keep, mainly because of religious restrictions.

The number of mouths to feed increased from 363 million in 1951 to over 500 million and is increasing by about 12 million a year. Per capita food grain consumption is 15 oz a day. For the future, it is hoped that new high-yielding varieties of wheat, rice, and maize will move into large-scale use.

India has no significant poultry industry although Indians are advised

to eat poultry rather than beef or pork. Poultry raising is controlled by the veterinary department of the government. Government poultry representatives, supervisors, county officers, engineers, and medical officers make too complicated a system. Markets for poultry are also controlled by the government. Poultry representatives show raisers how to vaccinate. When India became independent in 1947, it started raising Rhode Island Red chickens and White Leghorns, but it still does not have enough eggs or meat for the populace.

Pakistan

Pakistan faces problems similar to those of India. Population growth is compounded by the influx of seven million Muslims from India. The Comilla Academy and the Peshaware Academy are training local governing bodies to plan and implement programs in agriculture and community services. Pakistan has mapped an ambitious program to increase irrigation, fertilizer use, and research to improve crop varieties.

Philippines

Los Banos is the country's primary research and training resource in a battle to feed a rapidly expanding population which is likely to double by 1980. Ducks are bred for meat in the Philippines, since they grow faster than chickens and are fed in the rice fields where they help keep down weeds. The Faculty of Agriculture at the University of Mandalay offers courses in poultry husbandry.

Rice culturists in the Philippines test varieties from around the world for their ability to produce a heavy yield under tropical conditions and resist the depredations of disease and insect pests. The rice collection now numbers 10,000 varieties. Researchers have produced rice plants with short, stiff straws that increase their yield when fertilized, instead of "lodging." The plants have upright leaves to make good use of available sunlight. They are resistant to some of the most serious diseases. Rice yields are doubled in many cases.

MIDDLE EAST

The Middle East has had a high rate of population growth and an imbalance of food and people. The region has two large river systems—the Nile in Egypt, and the Euphrates and Tigris in Mesopotamia. It is an enormous expanse of steppe, semidesert, and desert. Only a fraction of the land area is now cultivated. The United Arab Republic pins much of its hopes for agricultural expansion on the new lands which will be available when the Aswan Dam is completed. A wide range of crops—corn, sorghum, sesame, peanuts, soybeans, and many others can be grown in

the Aswan area; wheat, barley, potatoes, forage legumes, and grasses are being studied. Corn is now grown on one-third of the country's cultivable acreage. Yields currently are only half that in the United States.

Syria is reasonably well supplied with food. The present population is expected to increase by ⅔ in the next 20 yr. If so, the country will have to cultivate more land and increase the productivity of land now in use.

Agricultural science is being developed in the Middle East through the School of Agriculture of the American University of Beirut. The University conducts research in poultry husbandry and provides graduate, undergraduate, and vocational training to students from many countries.

Since Israel is now using all of its available fresh water, scientists are studying ways in which salt water can be made usable. Their scientists are studying the mechanisms by which drought-resistant plants grow, use their water, and resist salinity. With this information, they will know better how to adapt plants to extreme conditions.

EUROPE

Netherlands

The mixed feed industry of the Netherlands is managing to get the most out of a restricted import market for grains (Tables 5.3 and 5.4). Imports are vital to the Dutch livestock industry which cannot obtain enough grain at home and has increasingly been threatened by high import charges built into the European Economic Community's Common Agricultural Policy (CAP). During the step-by-step implementation of CAP which brought common grain prices to all EEC countries, except Italy, the cost of grain imported by the Dutch mixed feed industry rose steadily.

In the Netherlands the mixed feed producers have met this challenge by becoming sophisticated feed formulators, changing their formulas to include the most reasonably priced ingredients. The Netherlands is 1 of the top 5 importers of U.S. feed grains, the 6th or 7th largest purchaser of U.S. soybeans, and an important outlet for corn gluten feed and other mixed feed ingredients.

The Dutch mixed feed industry is the most advanced, efficient, sophisticated, and integrated in Europe. Although linear-programming was still in its experimental stages only 5 or 6 yr ago, it has quickly been embraced by the Dutch mixed feed industry. Computers have become the research tools and bookkeepers of the large millers who own and operate their own installations and who set buying and formulating guides for the small mills. Since the advent of computerized feed formulating, the industry has been able to maintain a steady upward trend in production.

The industry is still made up of many small producers. In 1966 and

TABLE 5.3

EUROPE—ANIMAL NUMBERS AND FEED CONSUMPTION, 1965

	Germany		France		Italy		Holland		Belgium	
	No. Animals	Feed Consump[1]	No Animals	Feed Consump.[1]	No. Animals	Feed Consump.[1]	No. Animals	Feed Consump.[1]	No Animals	Feed Consump.[1]
Chicken × 1000	82,296	2812	108,000	1861	110,000	960	41,363	1725	12,200	752
Hogs × 1000	17,723	1863	9149	1403	5450	500	3987	2200	1885	944
Cows × 1000	5854	1521	9090	616	4800	230	1695	1000	1025	633

[1]Feed consumption × 1000 tons

In southern France they desire yellow broilers and yellow corn, corn gluten meal, and additional xanthophylls are used.

AFRICA

Farming methods in tropical Africa are still primitive. Rainfall is often heavy. Africa needs to provide a better diet for its peoples and contribute towards feeding other continents. Present farming is wasteful and exhausts the soil. Many Africans support themselves by "shifting agriculture," clearing land from the jungle, burning the cover, and planting crops for 3 to 5 yr. As yields decline, the land is let lie fallow for years before repeating the process. With outside support, it can increase output and improve the quality of corn, soybeans, peanuts, cassava, yams, and grain sorghums.

Moslems are heavy eaters of eggs but fasting limits consumption. Moslems and Jews do not eat products killed by others. Chickens are flown alive to neighboring countries. In Ethiopia, small farmers with several dozen birds receive only $0.22 a dozen; whereas, eggs from 500-bird flocks sell for $0.38. Many Ethiopians would like to buy the better eggs, but they cannot afford to pay the difference. Ethiopia has three areas. The nomads of the Eastern section have no chickens; the northern section produces a lot of eggs, and several companies purchase eggs to sell to European countries.

Fish are taken from the sea, dried by the sun and ground. Niger seed, locally produced for salad oil, is not high enough in protein. White and Brown Leghorns are obtained from Denmark and lay 150–160 eggs per year. There are three experiment stations in Ethiopia.

Nigeria

Nigeria is a land of extremes. It has little resources to buy eggs. Eggs are sold in small units—even 2-egg packages. The man in the bush has the "bush" chicken. Peppers and palm oil are fed to make yolks yellow. Eggs sell for 35c per dozen and broilers for meat purposes 35c per pound live weight. In a typical small village each farmer would have 3 or 4 hens at the most. Chickens are scavengers. When rice is being harvested, they get plenty of feed. Bone meal, blood meal, maize, oyster shell, oil cake, and fishmeal are available but costly.

Best egg production is obtained in winter or dry seasons. Eastern Nigeria has many flocks of 200 birds or more. Elevation is 1,600 ft, temperature 82°F, and rainfall 65 in. 5 months of the year. Problems are rain and cold. Corn, fishmeal, soybean, and nut meal (peanut) are available but expensive. Vitamins and mineral supplementations are used. Hy-Line birds are popular and fairly good performance is obtained. Feed storage

duced. Over 90% of farm income is from the sale of livestock and poultry products.

In the last 15 yr, production of meat has risen sharply. Pork has doubled, poultry trebled, and beef and veal increased by 50%. Egg production has dropped. Seven percent of the farm income is from poultry. In the smaller flocks, it is the housewife who looks after the poultry and gets the income from the sale of eggs. Half the eggs marketed are handled by the Danish Cooperative Egg Exports Association.

Vertical integration promoted by the feed industry is fairly widespread. The production of ducks and geese is limited. Turkey production is small but growing. The number of laying hens in Denmark's egg production has dropped greatly during the last few years. The battery system is illegal in Denmark. Twelve thousand farmers produce broilers for poultry dressing factories, but ½ of the broiler production comes from only 600 individual flocks. Birds are slaughtered at 8 to 9 weeks of age. Each chicken is subjected individually to the veterinarian's inspection before being slaughtered.

Production of table poultry is around 75,000 tons annually, ¾ of which is exported to West Germany and Great Britain. Poultry production is more industrialized than other forms of animal production. Research and development in poultry is carried out at the Royal Veterinary Agricultural College. Denmark has 25 agricultural schools to train students in the basic principles of farm work.

France

The commercial poultry industry started about 10 yr ago. Broilers are of Cobb's strain. Protein sources are sunflower, rapeseed, and peanut meal. France does not produce many cereals but obtains them from Canada. Wheat is common. The price of cereals is very high and is fixed by the government and the Common Market. Sugary cereals containing up to 10% sugar are commonly used Liberal amounts of protein are used in feed because of the high price of cereals. Thus, higher protein levels are used than in the United States because protein is not the limiting factor. Growing rations contain 9 to 10% added fat, finishing rations 8%.

Chickens raised on range and given wheat grow very slowly and weigh 4 lb when 16 weeks old. The French housewife likes this type of bird because she roasts it. Chicken is not very popular and sells mainly because of the low price —not because of the flavor.

There is a very small market for eggs. Brown eggs with dark yellow yolks are desired. Xanthophylls, corn gluten meal, alfalfa, and carotenoids are used to color yolks. Wheat, soybeans, sunflower, corn gluten meal, and alfalfa make up the hen's diet.

In northern France they demand white broilers and white corn is used.

growth of a commercial poultry industry. Industry has been broadly developed and the national income has more than doubled between 1950 and 1960. These growth factors necessitate equal expansion of the food supply and a better quality diet.

Mexico now has 5 million broilers on feed and 40 million layers. These are commercial-size installations and from the viewpoint of housing, equipment and sanitation, genetic quality of stock, and intensiveness of the feeding programs, are managed as effectively as in the United States. About a million turkeys are of relatively minor importance.

Initially, most flocks in Mexico were fed domestic grains balanced by concentrates imported from the United States, but complete feeds were universally accepted when they became available. As the industry grew, this policy became impractical, primarily because of high freight and import duties. The change to domestic manufacture was due mainly to the desire to control all phases of the industry.

Formula feed volume runs 60,000 to 75,000 metric tons monthly, of which 90% goes to the poultry industry. Carbohydrate feeds are in balance with demand, however, local shortages develop because of inadequate storage capacity. The corn crop averages 5–5.5 million tons annually which is mostly white corn since it is a staple of the human diet. Wheat crops of 1,250,000 tons provide 300,000 metric tons of bran and shorts available for feeding. The milo crop exceeds 155,000 tons. Other grains contribute an additional 200,000 tons annually to the feed supply. Grain sorghum production will be increased because it will help remove the animal industry from direct competition with the human food demand for corn. It would also lower the cost of production of chicken and eggs. High energy feeds based upon the use of added animal fat or vegetable oil is impractical. Fat is extremely scarce, high in cost, and importation is not feasible.

There is a need for 150,000 metric tons of well-balanced high protein ingredients. Animal proteins of domestic origin are scarce and supplies unreliable. Until recently, domestic fishmeal was almost nonexistent. The principal vegetable protein meals are cottonseed meal (230,000 tons), sesame meal (58,000 tons), and peanut meal (36,000 tons).

The nutritionists in Mexico are confronted with the problem of utilizing products that vary markedly in analysis from source to source. Sesame meal is a desirable protein supplement for poultry. Its protein quality may be superior to that of soybean meal if the lysine deficiency is satisfied. Peanut meal is short of demand and high in cost. Minor quantities of corn gluten meal are offered and more recently, solvent-extracted, undecorticated safflower oilmeal. Protein sources are sesame and fishmeals with some blood meal, feather meal, meat scraps, cottonseed and soybean meal. Most feedstuffs have a limited amount of lysine. The inescapable conclu-

and handling is a big problem because 40-50% loss occurs from weevils, contamination, etc.

SOUTH AND CENTRAL AMERICA

Latin America is largely tropical having immense jungles, high mountains, and broad plains. Soils range from some of the most fertile in the world to bare subsistence levels. Some Latin American countries have sophisticated agricultural systems and are mobilizing resources to provide more food products for domestic consumption and export.

In the Caribbean, field trials are being undertaken to identify more productive crops and develop better methods of production. One of the world's leading institutions in tropical agriculture is the Imperial College of Tropical Agriculture, founded by Britain in the West Indies in 1920. Today, the college's descendant, the University of West Indies in Trinidad serves the food production needs of the area by training undergraduates and graduates for service as agricultural scientists and technicians.

Brazil has the potential for great agricultural growth, yet full development of the interior is still years away. It is improving its fishing industry to help alleviate protein deficiencies. Marine fisheries at the University of Sao Paulo provide training on fishing methods and processing.

Argentina, Colombia, Peru, Chile, and Venezuela are registering gains in livestock and poultry production. Located in the vast wheat and meat-producing area of the pampas south of Buenos Aires, Argentina's University of the South is strengthening its teaching, research, and extension services. Chile is developing a modern agricultural system designed to increase production rapidly by making research results available on farms.

MEXICO

This country has raised its agricultural production by 4.1% a year in the past decade. It is self-sufficient in wheat production. Yields of corn, beans, and cotton have doubled. It still faces, however, an uphill battle because of population growth of 3.5% a year.

Mexican research work on dwarf wheat and rice with higher yield potentials has attracted world wide interest. The International Maize and Wheat Improvement Center, established in 1963, is developing an international staff and programs at headquarters in Chapingo. Research has shown the protein quality of corn can be improved through genetic means and may become roughly equivalent to skimmed milk as a food. The Center has a germ-plasm bank containing several thousand strains of corn of known characteristics.

Mexico's fast growing population, increasing urbanization, and expanding industrial economy has provided it with a climate conducive to the

growth of a commercial poultry industry. Industry has been broadly developed and the national income has more than doubled between 1950 and 1960. These growth factors necessitate equal expansion of the food supply and a better quality diet.

Mexico now has 5 million broilers on feed and 40 million layers. These are commercial-size installations and from the viewpoint of housing, equipment and sanitation, genetic quality of stock, and intensiveness of the feeding programs, are managed as effectively as in the United States. About a million turkeys are of relatively minor importance.

Initially, most flocks in Mexico were fed domestic grains balanced by concentrates imported from the United States, but complete feeds were universally accepted when they became available. As the industry grew, this policy became impractical, primarily because of high freight and import duties. The change to domestic manufacture was due mainly to the desire to control all phases of the industry.

Formula feed volume runs 60,000 to 75,000 metric tons monthly, of which 90% goes to the poultry industry. Carbohydrate feeds are in balance with demand, however, local shortages develop because of inadequate storage capacity. The corn crop averages 5–5.5 million tons annually which is mostly white corn since it is a staple of the human diet. Wheat crops of 1,250,000 tons provide 300,000 metric tons of bran and shorts available for feeding. The milo crop exceeds 155,000 tons. Other grains contribute an additional 200,000 tons annually to the feed supply. Grain sorghum production will be increased because it will help remove the animal industry from direct competition with the human food demand for corn. It would also lower the cost of production of chicken and eggs. High energy feeds based upon the use of added animal fat or vegetable oil is impractical. Fat is extremely scarce, high in cost, and importation is not feasible.

There is a need for 150,000 metric tons of well-balanced high protein ingredients. Animal proteins of domestic origin are scarce and supplies unreliable. Until recently, domestic fishmeal was almost nonexistent. The principal vegetable protein meals are cottonseed meal (230,000 tons), sesame meal (58,000 tons), and peanut meal (36,000 tons).

The nutritionists in Mexico are confronted with the problem of utilizing products that vary markedly in analysis from source to source. Sesame meal is a desirable protein supplement for poultry. Its protein quality may be superior to that of soybean meal if the lysine deficiency is satisfied. Peanut meal is short of demand and high in cost. Minor quantities of corn gluten meal are offered and more recently, solvent-extracted, undecorticated safflower oilmeal. Protein sources are sesame and fishmeals with some blood meal, feather meal, meat scraps, cottonseed and soybean meal. Most feedstuffs have a limited amount of lysine. The inescapable conclu-

TABLE 5.5

COMPARISON OF MEXICAN DOMESTIC FEEDSTUFF SUPPLY VERSUS FORMULA REQUIREMENT FOR ESSENTIAL AMINO ACIDS

Amino Acid	Arginine	Lysine	Meth.	Cyst.	Trypto.	Glyc.
	(Gm per 16 Gm Nitrogen)					
Formula Requirements						
Broilers (0–6 wk)	6.0	5.2	2.2	1.7	1.0	5.2
Layers (22 wk on)	5.6	3.1	1.8	1.5	0.9	3.7
Available Domestic Feeds						
Cottonseed meal	8.0	3.9	1.2	2.4	1.2	5.8
Sesame meal	9.8	2.9	2.9	1.4	1.4	9.7
Peanut meal	13.4	3.2	1.1	1.6	1.1	5.6
Corn gluten meal	3.3	1.9	2.3	1.4	0.5	3.5
Safflower meal	5.5	3.2	1.8	3.7	1.4	5.1
Garbanzo (chick peas)	9.0	7.0	1.3	1.0	1.1	3.3
Corn	4.4	2.2	1.7	1.7	1.1	3.3
Milo	3.7	2.6	1.1	2.0	0.9	3.7
Restricted Import Feeds						
Soybean meal	7.9	6.3	1.5	1.3	1.4	5.5
Meat and bone meal	7.4	7.2	1.5	1.2	0.6	12.0
Fishmeal, 65%	6.6	9.0	3.1	1.2	0.8	6.9

sion at the present time is that Mexico's domestic protein feedstuff supply is short and lacks the strength needed to produce efficient poultry feeds.

A comparison of the essential amino acid pattern of available domestic feedstuffs with those necessary for efficient performance of poultry shows that lysine is the first limiting amino acid in poultry feeds (Table 5.5). The principal natural supply of this amino acid comes primarily through import channels and is subject to close control. Regardless of any improvement in supply of vegetable protein meals, poultry feeds in Mexico will remain high in cost until the lysine problem is adequately solved.

Garbanzo, or chick peas (*Cicer arietinum*) can be fed to growing chicks. Although only moderately high in crude protein (20%), they have 1.4% lysine. Like other legume meals, they are low in sulfur-containing amino acids. However, sesame meal is high in methionine, and can complement the protein in this respect. Garbanzo imparts a desirable yellow pigment to both broilers and eggs.

Alfalfa is widely grown in irrigated areas, and the quality of the dehydrated product is generally excellent. However, inert gas storage facilities are practically unknown, so that there is some loss of valuable nutrients during the off-season for alfalfa production. Corn and sorghum are principal grains.

Dried whey products and other unidentified growth factor (UGF) supplements are almost as broadly used in Mexico as in the United States, but are subject to import controls. Feed-grade vitamins and additives are in

use. Mexico abounds in nearly all of the mineral elements required by poultry. Low-fluorine rock phosphate occurs at several locations and calcite exists abundantly throughout the country in a high state of purity. Salt is obtainable as crudely evaporated sea water.

The poultry industry is very competitive. Broilers are grown on the floor but 95% of the layers are in cages. White Leghorn or hybrid-strain layers are used. The government limits the number of incubators in the country to control the number of layers. Egg production varies from 60 to 70%. Most of the "know-how" is based on its counterpart in the southwestern United States. Two universities conduct research on poultry. One in northern Mexico deals with the nutrition; the other in central Mexico researches nutrition and management. Several U.S. companies operate in Mexico. Nutritionists are from other countries as well as from Mexico.

Milestones in Nutrition, Feeds, and Feeding

Information on poultry feeds and feeding dates back at least 200 yr as a result of contributions from all over the world. Many of the advances have occurred in the present century and a considerable number in the United States. Some of the early workers were physicians, druggists, or chemists. Students, more concerned with the present, could benefit by tracing the unfolding of ideas and principles which are accepted today without question

The researchers mentioned are only representative of numerous others who contributed importantly to the historical development of the science of poultry nutrition. Prior to 1800, what took place during digestion occupied the interests of men like Remoir, Spallazani, and Hunter in France, Italy, and England. Experimenters would feed test meals to birds and then sacrifice them at various intervals to find out what had taken place. In 1777, Lavoisier and his colleagues revealed the basic facts of energy metabolism. He proved that energy for the animal body was the result of oxidation of nutrients, which up to that time was thought to be derived from mysterious sources.

THE DISCOVERY OF VITAMINS

Fordyce, in England, showed that birds need calcium, and Bousingault, in France, noted that iodine prevented goiter. Casmir Funk from Poland coined the word "vitamine" while working in England. He was trying to classify the compounds chemically. He was later found to be in error but the word "vitamin" carried on in the language of nutrition to designate nutrients of low concentration in feeds. More recently, certain vitamins have been crystallized and their properties evaluated. When vitamins became identified, it was no longer necessary to include materials such as wheat offals, yeast, milk, fish, and grass as sources of particular vitamins.

The advent of synthetic vitamins, amino acids and surplus fats rapidly changed the picture. It then became possible to use lower cost sources of protein and energy. Poultry feeds today no longer carry just main ingredients—oats, wheat, barley or maize, and oilseed meal, but also include a long list of additives.

A glance at the nutrient requirements of the National Research Council show a number of question marks and blank spaces where further information is needed. These gaps in our knowledge are being filled from time to time.

In 1850, the American Poultry magazine advised that chickens should be fed corn once or twice a day, and boiled potatoes, wheat, rice, barley, buckwheat, and anything else that they would eat. It was recognized that birds liked green feedstuffs but they discouraged this. In a poultry husbandry book in 1905, it was recommended that "johnny cake" (flour, buttermilk, and soda to make it light) be fed. Feeding was pretty much an art at that time. The first scientific experiments in feeding poultry occurred around the turn of this century. The experiment stations in Geneva, New York and in Wisconsin showed that chickens did better when fed mash than "johnny cake." It was common then to have a garden to provide root crops to tide the chickens over the winter. Cabbage and sugar beets were hung up in the pens so that the birds would get some green food in addition to the mash. It cut down on picking and fighting. Green feed was considered necessary to get the laying birds through the winter because they were thought to contain nutrients needed to supplement ingredients normally supplied by pasture. However, when birds are on pasture they obtain more than just green feed, i.e., insects, soil, and light (vitamin D).

FEEDS PROVIDE NUTRIENTS

Today, there is more intensive production and pasture is not depended on as it once was. It has been found that feeds contain specific nutrients which satisfy the needs of birds. A feedstuff, such as corn, contains protein, carbohydrates, fat, etc., but not in the right amounts or proportions. One of the more costly nutrients is protein which contains nitrogen, some sulfur, and very small amounts of phosphorus. During the digestion of proteins, they are broken up by enzymes in the body into amino acids, their so-called building blocks. In the test tube this can be done by enzymes or chemical hydrolysis. The amino acids are absorbed into the blood stream and form proteins characteristic of the flesh of birds or the contents of their eggs. Free amino acids are not stored in body reserves. In general, when the protein in the ration is supplied mainly by vegetable sources the biological value of the protein is less than in the case of animal protein.

The analysis of the ration gives crude protein, not pure protein. Crude protein contains in addition to pure protein, compounds which contain nitrogen but are not pure protein. These substances cannot replace proteins. An estimate of how much true protein is present can be made by using an empirical factor (6.25) with the nitrogen level given by the Kjeldahl determination. Some plants have more protein nitrogen than others. Cottonseed meal has true protein but not in the same proportion as in soybean meal.

Before 1900, farmers relied almost entirely upon feed grains and rough-

ages grown on the farm to feed their poultry. By-products of the milling, meat packing, oilseed processing, and other processing industries are products of this century. Not only did these by-products contain substantial amounts of protein but also minerals and vitamins lacking in feed grains and roughages.

MILESTONES

1913	Fat-soluble vitamin A recognized
1920-1925	Importance of calcium and phosphorus recognized
1922	Role of vitamin D in rickets making confinement rearing of poultry possible
1925	Essential trace minerals were recognized; nutritional anemia prevented by iron and copper
1928	Multiple nature of vitamin B discovered
1929	Effect of hen's diet on egg hatchability
1931	Alfalfa dehydrated to supply forage nutrients
1933	Vitamin A and carotene identified
1933	Vitamin K demonstrated as essential for blood clotting
1933	Riboflavin (B_2) isolated
1934	Importance of ratio of calcium to phosphorus established
1936	Vitamin D_3 most efficient form for poultry
1936	Thiamine was isolated
1936	Improved method for producing soybean meal
1937	Manganese found to prevent perosis
1938	Choline recognized as an essential nutrient
1939	Vitamin B_6 synthesized, vitamin E identified; riboflavin and niacin marketed commercially
1940	Vitamin E offered commercially
1941	Fermentation products discovered to be source of vitamin B-complex and UGF
1944	Animal protein factor demonstrated
1946	Folic acid discovered
1947	High energy feeds became practical
1948	Vitamin B_{12} isolated in pure form (animal protein factor)
1949	*Vitamin B_{12}* was offered commercially
1950	Antibiotics, nonnutrient growth stimulants were found to increase growth
1951	Methionine produced commercially
1952	Animal fats used in feeds for energy
1953	Antioxidants first used in fats to control rancidity
1955	Whey and fishmeal practical sources of unidentified growth factors
1956	Importance of calorie to protein ratio demonstrated
1957	Importance of zinc and selenium in nutrition discovered
1957	Linear programming and "least cost" formulation

PROMINENT RESEARCHERS IN POULTRY NUTRITION:

Researcher	*Contribution*	*Location*
Titus	Statistics in Nutr.	U.S. Dept. Agr
Bird	Proteins	Maine
Bethke	Vitamin D assay	Ohio Expt. Sta.

Researcher	*Contribution*	*Location*
Schwartz	Factor 3, selenium	NIH
Almquist	Vitamin K	U. Calif.
Lepkovsky, Jukes	Vitamin B-complex	Calif.
McGinnis	Inhibitions, enzymes	Washington U.
Hill	Energy relationships	Cornell U.
Carpenter	Amino acid availability	England
Scott, M. L.	Vitamin interrelationships	U. Conn.
Scott, H. M.	High energy rations	U. Conn.
Combs	Energy, protein	U. Maryland
Elvehjem	Niacin, pellagra	U. Wisc.
Norris	Trace minerals	Cornell
Dam	Vitamin K in blood clotting	Denmark

About 100 yr ago, Henneberg and Stohman, in Germany, devised a method for dividing the carbohydrate fraction of a food into digestible and indigestible fractions. The indigestible fraction is the crude fiber and the extract the digestible fraction. Organic nutrients were classified as carbohydrates, fat, protein, and minerals. These researchers introduced the idea that digestible nutrients were more important in determining the nutritive value of feeds than total nutrients.

About 1890, Lunn attempted to feed purified diets. This became a very valuable research technique and is used now to get basic nutrient requirements. Another milestone was in the 1910–1920 decade when Funk isolated some crystals which prevented or cured experimental beriberi in pigeons. Other nutrients have been isolated, synthesized, and proven to be essential to the health and well-being of poultry and other species.

FEED INDUSTRY BEGINNINGS

According to Wherry, the commercial mixed feed industry started about 1900. Prior to that time, feedstuffs were sold to farmers who did all the mixing that was done. About that time, the flour mills in Minneapolis were dumping waste bran into the river. Cottonseed meal was used mostly as fertilizer. Up to that time, soybeans had not been used in feeds. It took another 30 yr to bring them into the feed picture. The next source of feed ingredients came from the corn industry. Corn was hydrolyzed into sugar syrup, but the bran and germ by-products were not used. About 1900 some of the residues from a lard rendering plant and cottonseeds were distributed in a small way for chicken feed. On the West Coast, scrap from fish processing was also used. Some of the companies that produced these feedstuffs are still in business today.

Midwest packing houses ground bones to produce bone meal for poultry feeds. Distillers' and brewers' by-products became available. At first, they attempted to market these products in a wet or semisolid state, but ran into considerable trouble because they molded. About World War II,

it was decided to dry the material. Since that time dried products of the distilling and brewing industries have been used in all kinds of poultry feeds.

Linseed meal was popular in Europe prior to 1900 but an appreciation of its value came later in the United States. About 1910, equipment for drying milk by-products was developed in Chicago and dried skim milk and dried buttermilk were tried in poultry mashes. Much later came the recovery of blood as a dried meal and source of protein. There was a prejudice against blood, although the Germans had used it successfully. Around 1910, fishmeal was produced from fresh water fish at Port Huron, Michigan. Many companies got into the act with salt water fish.

In the 1930's around Decatur, Indiana, one of the largest soybean processing plants in the world, using solvent extraction equipment developed in Germany, was started. Previously, hydraulic means were used but the solvent extraction method worked better because it recovered more oil. The price of soybean meal depended on the market for oil. If there was a good market for oil, the meal was practically given away. Now, with a better understanding of its value, soybean meal stands on its own feet economically.

BY-PRODUCTS INTRODUCED

The commercial feed industry's growth is still closely tied to the introduction of new by-products. By far the most important of these by-products is soybean meal, called the "keystone" of modern poultry production. Soybean meal use nearly doubled between 1950 and 1960, and accounts now for approximately 55% of all high protein feeds available for feeding.

Following is a chronological history of the introduction of new ingredients:

1885 *Cottonseed* meal was first successfully manufactured in New Orleans by Paul Aldige by extracting the oil from cottonseed.

1888 *Corn gluten feed* was first manufactured and marketed in Buffalo; corn gluten meal was manufactured in Chicago.

1890 *Meat scraps* began to be used for feeding.

1898 *Blackstrap molasses* was first used in feed when it was added to linseed meal and standard middlings in Chicago.

1900 *Tankage* was used in poultry rations after experiments demonstrated the value of this supplement.

1900 *Linseed meal* was used extensively in Europe prior to 1900, but it was slow to catch on in this country; many tons were exported because of lack of U.S. demand.

1900 *Alfalfa meal* was first used in poultry rations.

1904 *Bonemeal* was included in prepared poultry feeds.

1908 *Distillers' and brewers' grains* were developed by using efficient drying methods and the dried products gained acceptance and markets. These by-products had been fed undried for years prior to 1900.

1910 *Fishmeal* originated on the West Coast although it was not extensively offered for sale until about 1915. Fishmeals were first tested at Cornell University in 1915 and shortly after they were used in commerical poultry mashes.
1915 *Dried buttermilk* was first used in commercial poultry mashes in Chicago after drying process was perfected.
1920 *Dried skim milk* became available and was used in formula feeds.
1922 *Soybean meal* was first produced in the United States, although some was imported before 1915.
1952 *Protein soybean meal* (50%) produced for poultry feeds. The introduction in low-fiber broiler and layer rations in 1955 created a strong demand for this ingredient.
1954 *Animal fats*, such as tallow, were added to poultry rations. Fats added energy, improved feed texture, and eliminated dustiness. Other animal, vegetable and poultry fats are used now also.
1955 *Poultry feather meal* became available.

Feed Manufacturing Highlights

1848 Cotton bags first manufactured to replace wooden barrels
1870 Both porcelain and cast steel rolls used for flour milling and grain processing
1886 Jute imported from India used for making bags
1895 Hammer mills in use
1900 Attrition mill designed and patented
1905 Commercial electro-magnets became available
1909 Horizontal batch mixer built
1910 Volumetric feeders for line mixing
1910 Automatic hopper scales available
1911 Commercial pellet mill
1913 Molasses feed mixer
1914 Horizontal batch mixer
1916 Molasses regulating and proportioning equipment
1918 Commercial vertical mixer
1919 Cotton bags with dress print design
1924 A machine for pelleting high molasses feeds
1927 Batch mixing system, forerunner of "push button" mill
1930 Pellet machine and cuber
1931 New type pellet mill using a steel die
1933 High speed molasses feed mixer
1940 Pneumatic equipment for handling feeds
1941 Alnico permanent plate magnets
1942 Bulk truck for delivery of feed in bulk to the farm
1945 "Tote" bins for bulk feed handling
1946 Extruder for making pellets with 30 to 50% molasses
1947 Formula feeds in crumble form
1948 Paper bags for feed industry
1949 Weigh buggy
1950 Horizontal pellet cooler
1950 Liquid metering pump and equipment for handling animal fats
1955 A multiblender machine for conditioning, feeding, and applying molasses, fats, and fish solubles individually or in combination
1955 Feed mill to utilize punch card mixing control system; electronic feed panel for proportioning and mixer control

1957 Multiduty machine capable of producing hard pellets, high molasses pellets, and molasses feeds in meal form
1957 Full drop-bottom horizontal mixer
1957 Expansion pellet mill
1960 Square vertical mixer imported from Holland
1961 Cone-shaped vertical mixer with rotating screw

About 1920, there developed a business in molasses feeds. Molasses is produced from cane sugar, sugar beets, and corn refining. Years ago, molasses feeds were made by sprinkling dried grains with molasses. This produced masses about the size of croquet balls which after drying were ground with other feed. Now, it is blended with special equipment in many different types of livestock feeds.

Of more recent origin is the alfalfa industry. Alfalfa is cut and dried in special equipment almost instantaneously by oil furnaces. This product came into use about 1930.

Almost year by year for some time, a new vitamin or trace mineral was announced. Years ago, it was common to put cod liver oil in feeds as a source of vitamins A and D. Now other sources of these vitamins are used. There was a controversy at one time whether it was cheaper to put birds in sunlight which would supply vitamin D or put them in sheds and feed them cod liver oil. The modern poultry industry would have never developed as it has if it were not learned that vitamin D would substitute for sunlight.

There was considerable criticism in the 1930's of the commercial feed industry on the basis of claims that manufactured feeds contained weed seeds. These would pass through the animal into the manure, which if it were put on fields, would cause problems. However, it is the practice of mills to remove weed seeds and grind them up very finely so that they cannot germinate.

About this time, more feed control laws were enacted to protect the feeder. New regulations came in regularly to make certain that the feeder gets what he pays for. As the feed industry grew, another controversy developed—open formulas versus closed formulas. Some feed manufacturers wanted to protect their formulas which they had developed as a result of costly experimentation. A list of ingredients in the feed was not given the feeder. Open formula feeds were marketed by the cooperatives. The feed tag, attached to the bag, would list every ingredient and tell how much of each was in these feeds. Commercial feed companies claimed that the manufacturer could make substitutions so that the feeder would benefit in lower costs. Actually, both types of feeds can do a good job if properly formulated.

A feed tag is sometimes very confusing. It tells exactly what is in the feed, but perhaps some concentrates will be listed which are very complex.

VITAMIN RESEARCH

An amazing number of new discoveries have come from years of effort of scientists at agricultural universities, land grant colleges, U.S. Dept. of Agr., and feed industry research farms. More progress has been made in improving the production of poultry meat and eggs in the past half century than in the previous 25 centuries. Scientifically formulated feeds for poultry have contributed greatly to the variety, abundance, and quality of food available in the United States.

Although the feed industry is rather recent, the science of nutrition is not. Some important advances were concerned with poultry but many derived from knowledge developed with other species. A large part of the science of nutrition is applied chemistry and physiology.

There was a succession of vitamins discovered—A, D, and B-complex. All the nutritional factors required for top performance are not known even at the present time. Those unknown are called *Unidentified Growth Factors* (UGF) and represent only 1 or 2% of the feed. These factors are in such feedstuffs as alfalfa, fish solubles, brewers' yeast, distillers' solubles, and whey.

The prevention of leg weakness in chicks by 1920 was accomplished by the discovery of accessory factors or vitamins. This development was of utmost practical significance to poultrymen. It enabled the industry to move indoors and rear chicks in confinement at any time of the year.

Dependence on yellow corn for vitamin A became the established practice. A few years later, dried skimmilk became available and prevented curled-toe paralysis which appeared occasionally in young chicks. By 1934, the preventive factor in milk products was shown to be a yellow pigment called lacto-chrome and subsequently, riboflavin. This factor was needed for hatchability as well as growth. In the 1930's, it was observed that high levels of calcium in the chick diet accentuated development of slipped tendons, or perosis. Manganese partially prevented this abnormality and was useful in mash mixtures for layers and breeders. It is used commonly now as a precautionary measure since the cost is trifling.

During the 1940's soybean meal was found to give satisfactory results in replacing much of the animal protein concentrates used. Although raw soybeans contain substances that inhibit growth and egg production, soybean meal is of great practical importance because it reduces the cost of the mash. However, it was not possible to eliminate all animal protein concentrates for growth and hatchability. In 1948, vitamin B_{12} was isolated from liver extract and evidence proved the "animal protein" and the "cow manure" factors contained vitamin B_{12}. However, vitamin B_{12} is only one part of the animal protein complex.

About this time, it was found that the source of phosphorus in rations determines its value for chick growth. In cereals and legumes, the chief

source of phosphorus is phytin. About ⅔ of the phosphorus in these feedstuffs is contained in phytin which is not utilized as well as inorganic phosphorus such as tricalcium and dicalcium phosphate or bone meal.

In the middle 1930's, researchers noted that high energy rations grew chicks faster and promoted better egg production than rations of medium energy content. This laid the groundwork for more efficient utilization of nutrients.

AMERICAN FEED MANUFACTURERS ASSOCIATION

Mr. Ed Glennon, President, AFMA stated, "Early in this century feed manufacturers were confronted with problems resulting from inconsistencies in state regulatory laws. Inequities in transit rates were evident. Some few unscrupulous manufacturers were said to be more concerned about sales, than science or service. Farsighted leaders began to think about the future for this new industry. They recognized the potential of group effort in solving problems common to the industry, and in bringing dignity to an industry destined to become an integral part of agriculture.

"In May, 1909, 17 manufacturers met in Chicago to organize the American Feed Manufacturers Association. The first activity of the young Association was in the field of feed control relations. Work of the first committee, the Feed Control Relations Committee, has continued uninterrupted since 1909. Perhaps this committee has done more than any other to establish close harmony, honest manufacture, and intelligent regulation.

"World War II was a turning point for both industry and the association. The industry had grown to a billion-dollar giant and some 6,000 manufacturers were turning out branded feeds when bombs dropped on Pearl Harbor. The association in 1941 established the Nutrition Council which has become one of its most valued and active groups.

"The advent of medicated feeds, the rapid changes in production techniques, and growing importance of detailed poultry management programs caused the association to institute new programs in these areas in keeping with the changing times.

"By the mid-fifties, the AFMA established a Market Research Division. Through this division, the work of the Poultry Survey Committee was initiated; statistical information involving the industry was expanded; and programs were developed to isolate characteristics of a rapidly changing industry.

"In 1957 the National Feed Show was first staged in conjunction with the AFMA convention. The combined event became industry's top double-barreled attraction, biennially bringing together more people from more countries than any other feed function.

"Thus, the American Feed Manufacturers Association has grown in

stature to a position recognized as outstanding in service and accomplishment. It is the only national spokesman for the feed manufacturing industry and it enjoys the confidence of those whom it represents and serves."

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Poultry—The Animal

ORIGIN OF DOMESTIC FOWL

The Red Jungle Fowl (*Gallus gallus*), the ancestor of the present fowl, ranged from Northeast and Central India, Southern China, and Southeast Asia to Sumatra, Java and Bali. The place where the birds were most concentrated was northwest of the Dholkhand Forest and consisted of an upper story of sal, large banyan trees, a middle story of small trees (*Ehretia laevis, Mallotus phillipensis, Zizyphys, Jujuba*) and an understory of tall herbs (*Adhatoda vasica*) and bunchgrass (*Saccharum arundinaceum*).

The relatively high density of jungle fowl in this area was related to the food supply. Termite mounds are common. The small fruiting tree, *Ehretia laevis*, is abundant. Jungle fowl perch in its branches and eat the small red fruits. Banyan trees (*Ficus bengalensis*) and other fruit trees are also present. Abundant elephant droppings provide a source of food for jungle fowl in the form of various dung-inhabiting insects. Tall bunchgrass, known as sarkanda grass (*Sacchareum arundinaceum*) has tall, spreading leaves which provide good concealment for young chicks.

Crops of birds have contained 30 different kinds of seeds (*Shorea robusta, Zizyphys, Carissa*, rice and other jungle grasses), insects of various orders, spiders, snails, earthworms, and lizards. Jungle fowl eat a wide variety of fruits and seeds which become available at different seasons—fruits of banyan (*Ficus bengalensis*) trees, mulberry (*Morus*) and chamro (*Ehretia laevis*) trees, as well as species of *Carissa, Flacourtia, Ficus religiosa, Zizyphys, Grewis, Cordia* and *Eugenia*.

In the sal forest, there is a very heavy infestation of geometrid larvae. These caterpillars feed on the pollen of the sal tree and are, in turn, fed upon by jungle fowl. Termites are also an important seasonal food. As in the case of fruits of trees, different species of insects are available to jungle fowl at different times of the year. Because of their increased availability during the period of early growth, termites are particularly important.

From the original wild fowl of the bamboo jungles of India have developed birds with fighting propensities and beauty of form and plumage as well as birds for table meat and abundant egg production. Primitive types have been developed into breeds and varieties with diverse characters adapted for different purposes. The production of eggs and poultry meat has become of more economic importance than formerly.

CHICKEN, A BENEFACTOR OF MANKIND

The chicken is one of man's best servants. It is one of the most efficient converters of those feedstuffs which people will not consume for one reason or another. It is omnivorous and devours almost anything. The efficiency of a good laying hen ranks close to that of the dairy cow and surpasses the pig.

The chick is more sensitive to lack of nutrients in the diet than is the laboratory rat. It was thought at first that this sensitivity would be a handicap because it was hard to keep chicks alive on diets that would support rats fairly well. For example, a dietary supply of amino acids, certain vitamins, or minerals given to rats would not permit chicks to maintain themselves. Eventually, this higher sensitivity of the chick to the various factors proved a great advantage in bringing to light new information on vitamins, minerals, and amino acids.

The great advantage of chicks for experimental work is the capability of hatching them in large numbers at any time of the year. With large numbers, greater accuracy of assay can be obtained. After hatching, the chick does not have to be weaned but can take care of itself if it has warmth, water, and a good diet. The nutritional needs of humans are more like those of the chicken than those of the rat. The chick is the preferred animal to determine vitamin A activity in substances which may contain several different forms of this vitamin. The chick also has played an important part in the development of knowledge of vitamin D. Many thousands of chicks are used by feed control laboratories each year in testing for vitamin D. There are several forms of vitamin D and the chick responds differently than other animals. The chick needs more vitamin D than does the rat; it requires vitamin D_3 rather than D_2 which is required by four-footed animals.

CHICKENS AS LABORATORY TEST ANIMALS

In 1897, a medical officer in the Dutch East Indies noted that fowls fed the garbage from the local prisons developed a paralysis similar to that which affected humans. Subsequently, he fed some pigeons whole rice and rice with the outer layers removed (polished rice). The birds fed polished rice developed paralysis, designated as polyneuritis. This was the first time a disease of dietetic origin was produced experimentally. Polished rice lacks thiamine.

Muscular dystrophy is a disease of humans and also has its counterpart in chickens. It involves vitamin E and the mineral selenium, as well as the amino acids, cystine and methionine. The chicken is also an excellent test animal for riboflavin. A nutritional disease involving poor blood clotting due to a lack of vitamin K was first produced experimentally in chickens. This vitamin occurs in green feeds and is synthesized by bacteria.

The chick was the animal used in biologic testing during the detection, isolation, elaboration of structure, and ultimate synthesis of vitamin K.

The need for pantothenic acid was disclosed primarily with the chick. Lack of this vitamin produces dermatitis and poor growth in the chick. Skin disorders also are involved in a deficiency of biotin. Raw egg white contains a protein called "avidin" which inactivates biotin.

Chicks were also involved in the identification and isolation of vitamin B_{12} and are most effective in assay for this important vitamin. In the case of antibiotics and drugs, the chick was important in discovering the disease-fighting capacity of penicillin, aureomycin, streptomycin, nitrofurans, etc. Antibiotics are now fed to poultry to help them grow better and stay healthier.

Deficiency of manganese causes slipped tendons in chicks. Other minerals studied intensively with the chick include potassium, magnesium, calcium, phosphorus, iodine, zinc, copper, molybdenum, and selenium.

In vaccine developments, the chicken had a very important role. The egg is a remarkable product. It comes in packaged form, is usually sterile, and contains almost all elements important for the development of life. It is valuable for the culture of many types of viruses and thousands of eggs are used for this purpose. In the investigation of viruses, it is necessary first to isolate them in relatively pure form, uncontaminated with other organisms. The incubating chicken embryo proves ideal for this purpose, since it is usually a sterile medium and provides living cells which virus particles can invade and replicate themselves. The egg is used in the preparation of vaccines for diseases such as yellow fever, mumps, small pox, rabies, psittacosis or parrot fever, and avian encephalomyelitis. Eggs are also used in cancer research.

NECESSITY TO IMPROVE FEEDS

The addition of vitamins, minerals, and antibiotics as feed additives, and use of high energy components, improved poultry feeds. These can well spell the difference between failure and success in a commercial enterprise. Naturally, the most scientifically balanced rations will not make a good layer out of a hen unless she possesses these qualities through genetics. A naturally poor hen will never do much even though she be given the best of everything. By the same token, a naturally good layer will do poorly if fed inadequately. So, it takes teamwork of the scientists of the different disciplines to come up with the most profitable program to obtain optimum performance of the birds. Modern mass production of poultry requires basic knowledge in a number of fields.

HOW MUCH SHOULD A LAYER-TYPE PULLET WEIGH?

The weight at 20 weeks depends on the temperature and the light program under which the birds were grown. Nutrition plays a part, as does health and, of course, genetics. Healthy flocks of egg-type Leghorns average between 2½ and 3 lb at 20 weeks of age. The weight range for individuals within a flock is greater than that between flocks. Temperature affects feed consumption and, therefore, body weight. For every degree Fahrenheit above 63°, there is 0.8% reduction in feed consumption. At 80°F birds eat 13.6% less feed than at 63°F. This is because birds have a lower energy requirement at 80°F than at 63°F.

Birds hatched in the spring and grown in warm weather weigh less at 20 weeks of age than pullets grown in colder weather. A wide range of body weights within a flock results in a lower peak of egg production because individual birds mature at different times and reach production on different dates. Lighter birds mature slower but lay as many eggs as heavier ones during a 12-month period. Light birds are not necessarily sick, although sick birds will undoubtedly be lighter than healthy ones.

NUTRITION AND BODY WEIGHT

Weight at sexual maturity can be delayed and body weight at the inception of lay reduced by restricting feed. This involves limiting the amount of feed put before the birds, feeding high-fiber diets so that the birds cannot eat enough to satisfy their energy needs, or feeding unbalanced protein. The birds try to compensate for the reduced body weight by eating more feed. Several weeks prior to the onset of lay, birds produce more estrogen which brings about a very rapid expansion of the ovaries and oviducts and a rapid increase in body weight.

Nutrition is particularly important during the early stage of lay. The pullet is still growing and a daily nutrient allowance is needed for growth as well as for body maintenance and egg production. If feed intake is too low at this time, birds will not peak properly; body weight will not increase and may actually drop. Therefore, continued body weight gain during the first eight weeks of production is an excellent indicator of a proper level of nutrition. The advisability of delaying sexual maturity of layer-type birds by restricting feed remains a controversial topic among researchers. Most nutritionists agree that sufficient delay can be obtained by controlled lighting.

FUTURE PROSPECTS FOR GROWTH OF BROILERS

From time to time there have been reports of exceptionally fast growth of broilers along with improved feed conversion. By feeding certain in-

gredients in high efficiency rations, 3-lb birds have been raised in 6 weeks on as little as 1.28 lb of feed per pound of bird. These experiments use unconventional feedstuffs not available practically at the present time and only males of a rapidly growing cross. Some of the birds reach the weight of 1 lb at 3 weeks of age on 1 lb of feed per pound of weight. Productive energy of the rations are 1,745 Cal per lb in semipurified rations and protein is as high as 40%.

FEED INTAKE AND EGG PRODUCTION

The efficiency of egg production, measured as the amount of feed required to produce 1 doz eggs, improves rapidly as the rate of egg production increases. After the requirements for maintenance have been met, it takes approximately 3 lb of feed to produce 20 eggs. Efficiency increases rapidly as egg production goes up because the additional feed requirement is relatively small in comparison to the need for maintenance. Heavy hens need more feed for maintenance than light hens because they have to support a larger productive machine. The high overhead costs of heavy breeds make their efficiency less than that of the light hen producing eggs at the same rate.

If inadequate feeder space or some kind of mismanagement reduces feed intake, what can we expect to happen? Egg production will continue only a short time, partly at the expense of body weight. It will then be reduced to the rate which can be supported by the availability of feed supplied. A restriction of 11% in the feed intake decreases egg production 25%. "The most important pound of feed consumed by the bird is the last one." Every essential nutrient has a bearing on efficiency of egg production because a deficiency of any one of them lowers the rate of production or interferes with effective utilization of the ration. Hens tend to regulate their feed consumption to meet energy needs for maintenance, reproduction, and weight gains.

During much of the year there will be little or no difference between high energy rations (900 + Cal per lb) and rations considerably lower in energy value. In cold weather, high energy rations produce more eggs because hens may be unable to consume enough low energy mash to meet their needs for maintenance and maximum production. The size of the difference depends on the severity of the climate. To get top production throughout the year in the northern tier of states, a ration containing at least 900 Cal of productive energy per pound is needed. Higher energy rations are highly digestible which results in a smaller percentage of the ration appearing in the droppings. Coupled with a lower feed consumption on high energy rations litter problems are minimized. Pullets fed high energy rations tend to maintain body weight during cold weather when the weight maintenance problem is more acute.

ENERGY AND EGG PRODUCTION

The practical range of energy values for hens ordinarily is from 750 to 950 Cal of productive energy per pound of feed. Within this range the efficiency of egg production is practically a linear function of the energy value of the ration. A change of 100 Cal in the energy level of the ration produces a corresponding change of approximately 10% in the efficiency of production. Maximum efficiency results only from a complete understanding of all the nutrient requirements and balances which play a part in the efficiency of egg production. Will the use of high energy rations tend to produce excessively fat birds, especially during hot weather? Probably not, although it is possible some strains of chickens may be adversely affected.

FEED PRICES AND FEEDING VALUE

Nutritionists have to have some convenient means of comparing the relative feeding value of different feedstuffs in order to work out formulas that will nurnish nutrients at their lowest possible cost. The prices of various feeds are not guides to their actual feeding value. Feed prices change from season to season and often from month to month depending largely on supply and demand. As a result, a formula that is most economical today may be out of line in a few months. When feed prices change decidedly, the nutritionist should make whatever changes are necessary in the ration to take advantage of a new situation.

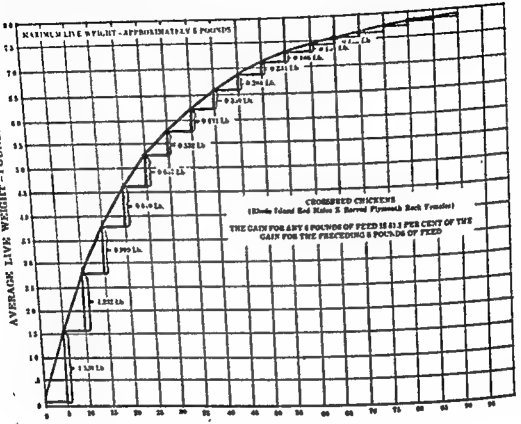
TEAMWORK SCIENTISTS NEEDED

Advances in poultry nutrition have opened an entirely new vista of research and understanding. It has brought the physiologist, biochemist, pathologist, veterinarian, and nutritionist into a common conclave of cooperation and mutual interest. No longer can the several fields be divided into distinct circumscribed and restricted areas where others "fear to tread." For now, it is realized that all of these areas are, in fact, one. To serve the farmer, researchers in both nutrition and disease must operate in strict coalition. There is no sharp line of division between sick and healthy animals; only a progressive and graded slope from the apparently healthy to the morbid or dying animal. Under practical farm conditions there are not many completely healthy animals. Many animals are sick or diseased to some extent all the time. Some are obviously in poorer health than others but all are in one way or another subject to the ills to which flesh is heir.

GROWTH

The rate of growth of poultry depends on a number of factors, such as species, sex, age, as well as on the adequacy of the diet and the quantity of feed consumed. Ducks grow more rapidly than chickens; males grow more rapidly than females. The rate of growth increases with age for a time and

then decreases. The more feed an animal consumes, the more rapidly it gains weight. Young, actively growing birds make larger gains in live weight per pound of feed than do older ones. As birds increase in weight, gains on a given quantity of feed decrease.



Courtesy of Dr Harry Titus and the Interstate Publishing Co., Danville, Illinois

FIG 7.1. FEED CONSUMPTION OF CHICKENS AS A FUNCTION OF LIVE WEIGHT

In Fig. 7.1 the average live weight of a group of male crossbred chickens is plotted against cumulative feed consumption. Data directly beneath the curve indicate pounds of gain and live weight that result from the consumption of each successive 5 lb of feed. Successive lots of 5 lb of feed produce only 81.1% as much gain as did the previous 5 lb. The 12th lot of 5 lb of feed produces only about 1/10th as much gain as did the first 5 lb.

Curve of Diminishing Increment

The relationship between live weight and ad libitum feed consumption describes a curve of diminishing increment. The curve can be used to estimate: (1) the cumulative efficiency of feed utilization to any specific live weight; (2) the live weight of an animal at which the animal plus feed cost of

gain in live weight is the least; (3) maintenance requirements of the growing animal; (4) the live weight that is attained as a result of the consumption of any specified quantity of feed; (5) the quantity of feed required to attain any specified live weight; (6) the efficiency of feed utilization at any specified live weight; (7) the cumulative efficiency of feed utilization to any specified live weight; (8) the cumulative maintenance requirement to any specified live weight; (9) the maintenance requirement between any two live weights; (10) the percentage of feed being used at any live weight; and (11) the live weight at which the animal plus feed costs per pound of gain is the least.

As a chicken becomes heavier, more and more of its feed is required for maintenance so a smaller amount of feed is available for growth. The net result is that the gain resulting from each successive unit weight of feed becomes progressively smaller. In a growing chicken, a large share of the feed is used for maintenance.

The largest gain per pound of feed is made when feed consumption is restricted to 50 to 70% of normal. Of course, it would not be economical to feed at this rate, even though a more efficient gain per unit weight of feed is obtained, since it would require more than twice as much time to produce the same weight of live chickens. Male chickens are more efficient in their utilization of feed for growth than are females. The efficiency of feed utilization for growth varies not only with the breed and kind of poultry but also with the type of diet and with the temperature of the environment.

Feed consumed by a pullet is used for growth, maintenance, and egg production; whereas, in the yearling hen, the feed is used mainly for the last two purposes. After enough feed has been consumed to take care of the growth and maintenance, 0.09 lb of additional feed is consumed for each egg that is laid. The quantity of feed required to maintain a chicken a year increases 10 lb for each pound increase in a chicken's live weight. A Leghorn pullet consumes 7.7 to 8.7 lb of feed per dozen eggs if she lays 100 eggs per year, but only 4.4 to 4.9 lb if she lays 200 eggs per year.

BODY COMPOSITION

High caloric diets cause an increased deposition of fats. Reducing the fat or caloric value of the ration by diluting it with an ingredient having no food value, such as oat hulls, causes birds to increase their consumption and weigh about the same. However, the amount of fat deposited in the body is less for chickens receiving diets containing large amounts of oat hulls.

On Long Island, New York, duck fatness was reduced by increasing the amount of protein, thereby producing a duck more acceptable to housewives. Only when animals receive an excess of energy over the amount which is required for optimum conversion of dietary protein into fatty

growth is the energy converted into body fat. Animals given just enough calories for maximum conversion of their dietary protein to tissue growth achieve maximum weight with a minimum storage of body fat. If the energy level of the diet remains high and the protein level is increased, the animals reduce their feed intake and still are able to obtain the needed protein and corresponding amount of needed energy required for maximum conversion of the protein to body fat. In broiler production, where premium prices are given for birds with a high percentage of body fat, the finishing ration should be low in protein and high in energy content.

In Maryland, studies on the effect of varying the C/P ratio of the ration on body composition of growing chicks included a series of rations that had sufficient energy density to insure that the chick's capacity would not limit its feed consumption. As the C/P ratio was widened from 35 to 70, a 2½ total increase in the body fat content was observed with relatively little difference in rate of gain. This positive correlation between C/P ratio and body fat content indicates that chicks are able to increase appreciably their energy intake in an effort to obtain sufficient protein. In addition to the C/P influence on overconsumption of feed and on body composition, the percentage of dietary protein retained in the carcass was greatly influenced by the energy intake of the chicks. Carcass fat content and percent retention of dietary protein were consistently increased as the energy intake of the chick was raised at each level of protein intake.

A marked loss in body weight which results from simple deprivation of food has been recognized from time immemorial. Of course, the deficiency diseases are examples of disorders that affect tissue composition and cause pathological changes.

EGG QUALITY

Nicarbazin fed to laying hens produces eggs with blemished yolks which in the most severe form have the appearance of rotten eggs. Blemishing occurs with as little as 0.0015% Nicarbazin in the ration. Storage of eggs increases the incidence of severe damage. White-shelled eggs are produced by brown-shell breeds The effect of nutrition upon blood-spots in chicken eggs has been investigated. Illinois research showed that feeding dehydrated, unjointed, young cereal grasses or permitting birds access to range substantially reduced the number of blood spots. Washington researchers claim that suboptimal levels of vitamin A cause bloodspots. Some hens produce eggs with much more thin albumen than others, genetically. It is commonly felt that practical ingredients normally used in laying rations have little effect on interior egg quality. Heredity is one factor and the season of the year is another.

Newcastle disease increases the amount of thin white as does infectious

bronchitis, infectious hepatitis, and coccidiosis. Certain fly sprays, if accidentally given to laying birds, cause thin whites. Cottonseed meal and cottonseed oil result in abnormal whites and yolks of eggs during storage. Certain sulfa drugs fed to chickens and turkeys cause them to lay eggs with very thin or no shells. Feeding Arasan-treated seed corn to laying birds results in the production of soft-shelled and irregularly shelled eggs. Several researchers have suggested that thyroid activity, known to be reduced by increasing environmental temperatures, may have some effect on egg shell thickness.

Composition of feeds can also affect egg weights. A layer feed should contain at least 17% protein and 900 Cal of productive energy per pound for maximum egg weight. A drop from these levels results in a decreased egg weight. There is a critical need for vitamin D_3, calcium, phosphorus, manganese, and possibly zinc to maintain strong egg shells.

HATCHABILITY

The effect of the maternal diet upon embryonic development has been demonstrated many times. Definite peaks of embryonic mortality, depending upon nutritional failure, has been demonstrated. The degree of deficiency in the stored materials in the egg determines the length of time embryos can survive. There is little evidence on the effects of either proteins or carbohydrates on development of the developing embryo or on hatchability except in general by affecting the plane of total nutrition. Rations extremely low in fat have been found to decrease the efficiency of carotene absorption. But they seem to have little effect on absorption of vitamin A. Vitamin D is another of the essential vitamins for reproduction. Rachitic embryos may be expected from maternal diets deficient in vitamin D, calcium, or phosphorus. Riboflavin, vitamins E and K, pantothenic acid, and biotin are doubtless concerned with embryonic growth and development. The developing embryo requires all the nutrients essential for growth and these must be supplied in the maternal diet. When they are lacking either a slow rate of growth, deformity, or mortality in the embryo results. There is a carryover of nutrients from the maternal diet to the offspring. As will be pointed out later, the pigmentation of egg yolks is due to xanthophyll from yellow corn and green leafy ingredients which are deposited in the yolk of the egg and provide skin pigmentation in the chicks derived therefrom.

RESISTANCE TO DISEASE

Evidence indicates the basic importance of protein metabolism in relation to the processes of natural and acquired resistance. This points to the conclusion that many important aspects of the problems of infection and

resistance are essentially nutritional. Malnutrition and infection occurring together are mutually aggravating and in poultry lead to more serious diseases than would be predicated from either alone. The relative importance of the various mechanisms involved is not known. Most of the severe deficiencies interfere with antibody formation, phagocytic activity, tissue integrity, and certain types of nonspecific resistance. They also cause changes in intestinal flora and in endocrine balance which, in turn, influence resistance to an infectious agent.

Everybody in the egg business has been reminded more times than he likes to remember that eggs contain a high level of cholesterol. A few years ago, dietary cholesterol was represented as a major causative factor of circulatory disease. More recently, suspicion has shifted to saturated fats in the diet. However, one still encounters people who avoid eggs because of the unfavorable publicity aimed at cholesterol in the past.

The relation of diet to circulatory disease is a very complex one. Florida researchers fed turkeys a practical turkey feed, except that it contained somewhat higher levels of protein, fat, and salt. There was no mortality during the 11 weeks of the experiment. When it was supplemented with diethylstilbestrol, blood plasma cholesterol increased more than 5-fold and 37% of the birds died of aortic rupture. When 1% of cholesterol was added with the diethylstilbestrol, blood plasma cholesterol was decreased, and only 6% of the birds died with aortic rupture. Here is one situation in which adding cholesterol to the diet decreased cholesterol in the blood. There is still much to learn about maintaining a sound, healthy circulatory system in turkeys, and other animals.

FLAVOR OF MEAT

If birds eat strong smelling materials, such as garlic or onions, their eggs and flesh will be tainted. Feeding too high a percentage of cod-liver or other fish oil and fishmeal (especially if stale) may result in the eggs and flesh of some birds, but not all, having a fishy flavor. Provided the recommended levels are not exceeded and only good quality fishmeal is used, there is no danger of the ration causing a fishy flavor in the eggs. It should be noted, however, that eggs sometimes absorb flavors after being laid if they come in contact with strong smelling materials, e.g., wood preservative and some insecticides.

The danger of the feeds causing a fishy flavor of poultry meat seems to be greater than in the case of eggs. Hence, during the last two weeks before killing, it is generally recommended not to feed any fish oils or fishmeal to table birds or at least to use only a small proportion (2½%) of best quality white fishmeal.

There is a significant difference in flavor between the cooked meat of birds grown under germ-free conditions and that from conventionally

TABLE 7.1

WEEKLY AVERAGE WEIGHT, GAIN, AND CUMULATIVE FEED CONSUMPTION AND FEED CONVERSION FOR COMMERCIAL BROILERS

Week	Males		Females		Mixed Sexes		Feed Consump./Broiler		Feed Conversion[1]	
	Weight	Gain per Week	Weight	Gain per Week	Weight	Gain per Week	Weekly	Cumulative	Weekly	Cumulative
	(Lb)	(Lb)	(Lb)	(Lb)	(Lb)	(Lb)	(Lb)	(Lb)		
1	0.19	0.19	0.18	0.18	0.19	0.19	0.14	0.14	0.74	0.74
2	0.38	0.19	0.35	0.17	0.37	0.18	0.30	0.44	1.67	1.19
3	0.69	0.31	0.62	0.27	0.65	0.28	0.49	0.93	1.75	1.43
4	1.11	0.42	0.98	0.36	1.04	0.39	0.68	1.61	1.74	1.55
5	1.63	0.52	1.39	0.41	1.51	0.47	0.92	2.53	1.96	1.68
6	2.19	0.56	1.78	0.39	1.99	0.48	1.06	3.59	2.21	1.80
7	2.78	0.59	2.23	0.45	2.50	0.51	1.25	4.84	2.45	1.94
8	3.35	0.57	2.66	0.43	3.01	0.51	1.44	6.28	2.82	2.09
9	4.02	0.67	3.13	0.47	3.57	0.56	1.56	7.84	2.79	2.20
10	4.57	0.55	3.53	0.40	4.05	0.48	1.55	9.39	3.23	2.32

[1]Pounds of feed required to produce 1 lb of live weight.

raised chickens. Meat from the former has a milder flavor and that from the latter has a stronger flavor. The flavor difference between farmyard and battery-raised chickens is due in part to bacteria in the intestine.

Present-day systems of dressing birds right after killing tend to produce a better product from a bacteriological standpoint and is more satisfactory for the consumer. However, the taste of broilers is claimed to be different now than in the "good old days." Some consumers assert that the modern broiler is not as palatable as the "vintage" chicken. Of course, nostalgic memories are notoriously unreliable because one is more apt to remember pleasures than vexations. There is no basis for the statement that more rapidly matured flesh is more insipid than flesh produced more slowly. Very likely, earlier methods of slaughter and evisceration with poorer sanitation and refrigeration caused a more gamey flavor. Birds were then stored overnight to make it easier to eviscerate. No doubt, this could be duplicated in the modern bird if desired. This is a storage not a feed influence.

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Anatomy and Physiology

INTRODUCTION

The skeleton of the bird's body is the framework which protects the vital organs and holds the bone marrow that produces red blood cells and some white cells. The bird's skeleton is compact, light in weight, and very strong. Some of its long bones are pneumatic, that is, penetrated by air sacs which extend from the bronchial tubes. These air spaces make the bones lighter which aids flight but in certain bones also help with respiration. Some bones are fused together giving greater rigidity to the body in forming strong structures to which large muscles used in flight are attached. The bones also serve as a storage place for calcium. The limbs are adapted for both flying and walking.

INTELLIGENCE

Birds certainly are not the most intelligent creatures but from an anatomical point of view they should be much less intelligent than they apparently are. Not only are bird brains surprisingly small, but they have a very small cerebral cortex. Since the cerebral cortex—the gray matter covering the brain—is largely responsible for intelligence, it has always been assumed that small cerebral cortexes in birds must be equated with low intelligence.

But this has not agreed with psychological tests given to birds. Despite the cerebral deficiencies, birds have done surprisingly well on the tests and in some cases even surpassed the results of mammals with larger cortexes. Ravens seem capable of counting a lot better than rats and elephants, supposed to be fairly smart animals. In tests in which animals had to figure out where food was hidden, crows, magpies, and ravens did better than rabbits and cats, though pigeons and hens were the worst and dogs the best.

The answer may lie with the striatum, a part of the brain that lies beneath the cortex. Though the amount of intelligence in mammals depends on the size of the cortex, this is not so in birds who seem to depend more on the striatum. An examination of the brains of the comparatively intelligent canary, crow, and parrot revealed a much more highly developed striatum than was found in the not-so-bright pigeon and quail. The bird's seat of intelligence is a bump on top of the hyperstriatum called the Wulst. Perhaps the much maligned bird brain will eventually make a key contribution to the understanding of how the brain works to produce intelligent behavior.

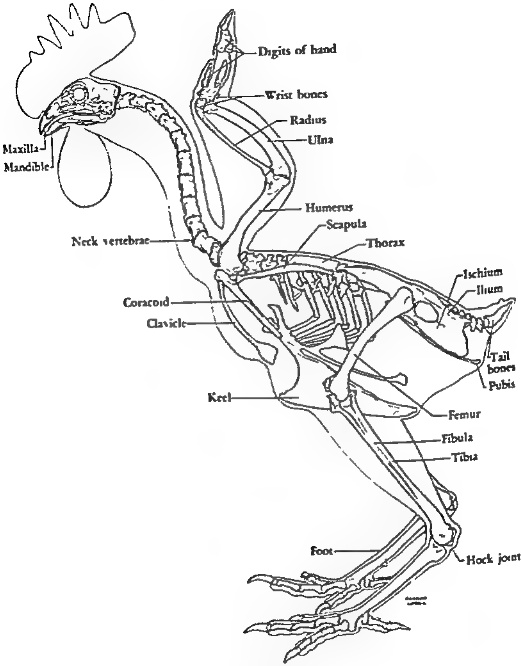

FIG. 8.1 SKELETON SYSTEM OF CHICKEN MODIFIED FROM LUCAS AND STETTENHEIM, AVIAN ANATOMY, INTEGUMENT U.S.D.A.

THE MOUTH

The mouth of the bird has a limited supply of salivary glands. The crop performs the functions of a storage organ and a meter for admitting food into the digestive apparatus. The small tube stomach (proventriculus) and the powerful muscular gizzard perform the task of mastication. The

bird has a large, well-defined pancreas and duodenum, a relatively short intestinal tract, large well-defined ceca, a short rectum, and a common excretory organ for both fecal and urinary waste. The crop and the gizzard are not necessary for survival and normal function, but the bird then must be fed a feed not requiring mastication. There is only a slight reduction in digestibility following gizzardectomy or ablation of the crop. Removal of the ceca can also be done without disturbing normal function. The overall digestive efficiency of the chicken is similar to that of other nonruminant animals. In general, the chicken has a highly efficient digestive apparatus.

Birds have no lips or teeth but a crop which allows them to eat large amounts of foods very quickly and pass them on gradually to the first part of the stomach, the proventriculus, which produces gastric juice. The food passes to the gizzard, an organ without counterpart in mammals, to be ground. It is doubtful whether much digestion takes place in the gizzard. Digestion and absorption are handled mostly in the relatively short, small intestine. The bile and pancreatic secretions enter the duodenum further along than in mammals. The large intestine is shorter and there are two well-developed ceca. The digestive system with which the chick or poult is endowed works at least as efficiently as that of the pig or the cow. Domesticated birds are just as handicapped as pigs in dealing with roughage. But with higher energy diets, conversion of food is second to none.

THE DIGESTIVE TRACT

The digestive tract or alimentary canal is a long tube from mouth to vent. Feed enters the mouth which has no lips or teeth. The esophagus or gullet and crop are just below the mouth. The tongue forces feed into the gullet where it descends to the crop. Here it is softened with water and saliva from the mouth; hard material such as whole grain remains 12 hr. The proventriculus or glandular stomach contains glands which secrete gastric juice. Feed passes through quickly, is mixed with gastric juice and goes to the gizzard, an oval organ with entrance and exit on the upper side (Table 8.1). Thick, powerful muscles covered internally by thick, cornified epithelium grinds the feed, aided by grit.

Feed then enters the small intestine where most of the gastric digestion takes place in the upper U-shaped loop called duodenum, but in the lower portion there is some further digestion and absorption. There are two blind pouches called ceca—4 to 6 in. long in a mature chicken at the junction of the small and large intestine in which some bacterial digestion and absorption takes place. The large intestine is short and absorbs moisture. The cloaca, a chamber common to both digestive and genital-urinary systems, ends externally at the anus or vent.

Accessory digestive organs include the following. The liver is mahogany-

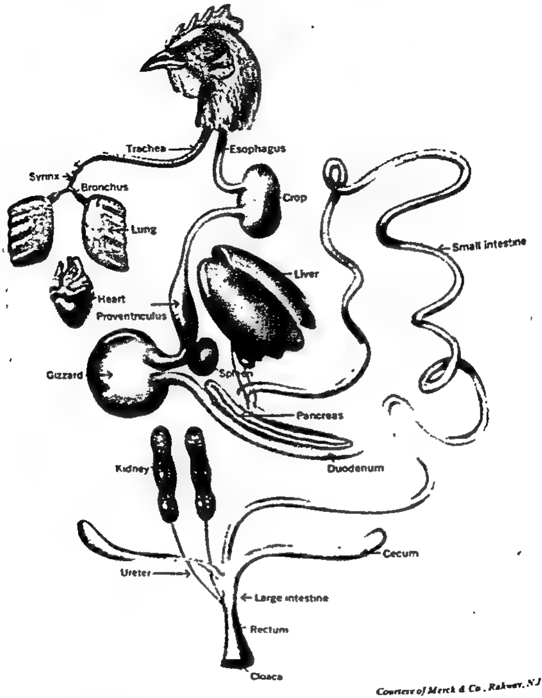

FIG 8 2 NORMAL ANATOMY OF DOMESTIC FOWL

brown in color, has two lobes and elaborates bile, a bitter, slightly acid, greenish-yellow fluid containing bile salts, cholesterol, lecithin, fat, pigments, and mucin. It aids in the emulsification, digestion, and absorption of fats, in the alkalinization of the intestines, and in the prevention of

TABLE 8.1

THE pH MEAN AND RANGE OF THE DIGESTIVE TRACT OF CHICKENS

Region	Mean	Range
Crop	4.67	4.39 4.82
Proventriculus	4.48	4.30 4.60
Gizzard	2.94	2.83 3.01
Duodenum	6.13	5.95 6.40
Jejunum	6.29	6.03 6.62
Ileum	6.58	6.36 6.81
Ceca	6.14	5.75 6.50
Rectum	6.82	6.62 7.21
Bile (gall bladder)	6.51	6.12 6.64
Pancreas	6.58	6.38 6.80

putrefaction. Some bile is stored in the gall bladder and empties through a bile duct into the duodenum; some goes directly from the liver to the duodenum through the bile ducts. The pancreas, a long, flesh-colored organ lying in the loop of the duodenum, secretes pancreatic juice into the pancreatic ducts which empty into the duodenum and acts on proteins, carbohydrates, and fats.

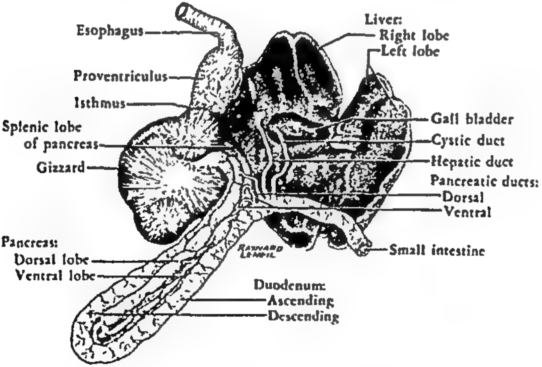

FIG. 8.3. DIGESTIVE GLANDS OF CHICKEN SHOWING DUCTS FROM LIVER AND FROM PANCREAS TO THE DUODENUM

Modified from Lucas and Stettenheim, Avian Anatomy, Biester and Schwartz, Disease of Poultry, 1965.

PHYSIOLOGY

Digestion

Digestion includes all physical and chemical processes by which the feed is broken down and made ready for absorption—swallowing, peristalsis, grinding in the gizzard, softening effect of water, action of enzymes and bacteria, etc. The undigested residues are excreted in the feces. The digestive juices are excreted from the walls of the digestive tract or associated organs and contain water, enzymes, etc. Saliva is secreted in only small amounts by poultry and contains ptyalin which converts some starch to maltose and helps soften food. The gastric juice contains water, HCl, pepsin, rennin, and breaks down protein; the duodenum contains water, bile, pancreatic juice, and intestinal juice. Bile emulsifies and saponifies fats. Pancreatic juice contains trypsin which acts on protein, amylopsin which acts on starch, and steapsin which acts on fat. Intestinal juice from the intestinal wall contains erepsin which acts on protein, invertases which act on sugars, and lipase which acts on fat.

Fifty-five degrees Fahrenheit is generally considered the ideal temperature for birds although some think it should be as high as 72°F. If it gets too cold or too hot, there are fewer eggs.

The time required for food to pass through the alimentary canal has been studied in several ways. (1) Birds are fed at a certain time and killed after suitable intervals. The location of the food is observed as it passes through the digestive tract. This is a crude way of measuring passage rates. (2) A dye is used for staining feed or a substance is fed that can be chemically analyzed. A refinement of this technique is the use of a radioisotope; there are certain requirements that radioisotopes or dyes must meet. First, they must not be metabolized or digested so they are broken down into another product and they must pass through the digestive tract at the same rate as food. (3) The passage of the feed is followed by visual observation of particular feeds; in some cases, such feed ingredients as oats or barley are fed to chickens or chokeberries to pheasants. These berries are eaten by pheasants in the wild; in the latter, the time that it takes for the first red color to appear in the droppings is recorded Oats can be used because not all of it is digested. (4) Using X-rays; a barium salt is fed and the passage rate measured as it goes down the digestive tract. The problem is that it does not pass through at the same rate as feed. (5) Using cannulas as tubes into the digestive tract. Several cannulas coming to the outside of the body where samples of feed can be obtained as it passes through the digestive tract should be used. (6) The common dye chromium oxide is used as a marker for passage rate. Pellets of food are sprayed so as to get a random sample. The radioactive chromium on the pellet is attached onto different ingredients. This radioactive feed is fed to the chicken to obtain passage rate.

metabolizability, and digestibility of the feed. By use of a bomb calorimeter, results can be expressed as metabolizable energy of that feed. Birds are placed in cages with waxed paper underneath. A motor pulls the paper at a constant rate. By knowing the rate of paper movement, one can measure within 15-min periods the time when a dropping was produced.

The crop is a storage place for the food but not all feed leaves the crop at the same rate. Certain feeds leave faster than others. It also depends upon the fullness of the crop. As to the time of disappearance from the crop: 5 gm of a mixture of wheat, corn, and oats took 1½ to 2 hr; 30 gm took 7½ to 9 hr and 60 gm 10 to 18 hr. Thus, the fullness of the crop and the material fed influence the time the food remains in the crop.

Each grain differs somewhat in its nighttime compared to daytime digestibility. In order to use metabolizable energy for a poultry ration, two assumptions are made. What happens to metabolizable energy when corn is ground, mixed with oats, barley, vitamin premixes, and other things? The chart shows that the metabolizable energy of corn is so much which refers to corn by itself. You make the assumption that it does not change when mixed with other feed ingredients or ground. There is the possibility that some change occurs when feeds are mixed together. A second assumption is that the metabolizable energy is the same irrespective of the age or the type of bird. This probably is not so. The metabolizability of corn for a baby chick is probably a little different than that for hens.

In the digestion of feed nutrients, carbohydrates are converted to simple sugars for absorption. Ptyalin and amylopsin act on the starch of the feed to change it to dextrin and then to maltose. Invertases act on maltose and similar sugars converting them to glucose or simple sugars. Pepsin in acid media changes the proteins progressively to metaproteins, proteoses, peptones, and peptides. Trypsin acts in the same way in an alkaline media. Erepsin converts proteoses, peptones, and peptides to amino acids. Fats are converted to fatty acids and glycerol. Alkaline salts from bile saponify, emulsify, and dissolve fats and fatty acids. Steapsin acts on the fat to produce fatty acids.

Digestion is less complex in poultry than in some animals. Nitrogenous products are not stored in the bladder but poured into the cloaca with feces as insoluble uric acids—not soluble urea as in some animals. Poultry have a short digestive tract like the carnivores, but consume feed and grind it like the herbivores. Compared to the ruminants, the amount of saliva secreted in poultry is very low.

The time for food to pass through the intestinal tract depends on the condition of bird and type of feed (Table 8.2). The number of hours is approximately the following: growing and laying birds 4; nonlaying hens 8; broody hens 12; first appearance in the feces—soft foods 2½; grains 3. Oats are retained longer in the crop than corn and wheat, whole corn longer

TABLE 8.2

THE TIME REQUIRED FOR FEED TO PASS THROUGH THE ALIMENTARY TRACT OF CHICKENS AND TURKEYS

	Age (Yr)	Av. Food Passage Time (Hr)
Young turkey hens	4 to 5 mo	2.27
Old turkey hens	1½ to 2½	3.52
Chicken layers	1 to 2	3.42
Chicken nonlayers	1 to 2	3.50
High temp (90°F)	1 to 2	3.46
Low temp (60°F)	1 to 2	3.51
Chicken hens	1 to 2	3.40
Turkey hens	1½ to 2½	3.45
Pullets	6 to 8 mo	3.12
Cocks	1 to 2	3.20

than cracked corn or corn meal, dry oats longer than boiled oats, and dry mash longer than wet mash. The amount of grain present in the crop is as follows: after 4 hr 75%, 8 hr 60%, 12 hr 40%, 13 hr 30%, 20 hr 14%, and 24 hr 10%. To clear the digestive tract entirely from corn 50 hr is required, from wheat 102 hr, and from barley and oats 120 hr. Cooking increases digestibility of starch.

Assimilation or absorption occurs largely in the small intestine but some occurs in the large intestine and ceca. To be absorbed, the nutrients must be in a liquid form. Simple sugars, amino acids, soluble minerals, fatty acids, and glycerols enter directly into the blood stream. Once proteins reach the proventriculus they are acted upon by hydrochloric acid and the proteolytic enzyme, pepsin. As the chyme moves down the gastrointestinal tract into the duodenum and jejunum (the second division of the small intestine extending from the duodenum and the ileum), various pancreatic and intestinal proteolytic enzymes are secreted and digestion proceeds. The net results of these activities is the breakdown of ingested proteins and the absorption of digestion end products. The secretions of endogenous origin contribute to the protein materials in the gut. In some animals, the digestive tract has a homeostatic system whereby exogenous protein is mixed with endogenous protein which provides a more favorable amino acid mixture for absorption. This has not been proved with poultry. There is control of secretion of digestive enzymes by the physical presence of feed in certain areas, neural control by vagus, and hormonal control. The rate of feed passage depends on the size of the feed particles, amount of liquid, and the amount of fat in the small intestine. The rate of absorption varies with the condition of the mucous membranes of the intestines, length of time in contact with the villi, activity of endocrine glands, the adequacy of vitamin intake, and especially the anterior pituitary and thyroid activity.

There is a considerable amount of endogenous protein excreted by the chick. Pancreatic juice contains about six mg of nitrogen per milliliter and there are about 30 to 40 ml of pancreatic juice excreted per day. This would amount to a total of 2½ gm of protein per day. The most active site of absorption of amino acids is in the upper jejunum.

The pancreas located in the loop of the small intestine adjacent to the stomach has two-fold functions: secretes digestive juices and the hormone insulin. Digestive juices enter directly into the intestine and the hormone, insulin, enters the blood stream.

The thymus gland is an irregular glandular mass extending from the thyroid gland up the neck. It becomes degenerate at the time of maturity.

EGG PRODUCTION

Ten days prior to laying the first egg, the pullet has hundreds of small yolks in her ovary about the size of sorghum seeds. When 100 days old, the pullet senses the circadian rhythm[1] of her environment. A major factor is the length of daily dark periods. She is stimulated by a succession of days during which the dark period becomes shorter each day, such as occurs from March to June in the United States. Egg production starts by stimulus to a hen's brain by nerves to the hypothalamus, and neural secretory cells to produce hormone(s) known as releasing factors which seep through the capillaries to the portal system of the pituitary gland. The nerves are the telephones; the hormones are messengers. This stimulates specific cells of the anterior lobe of the pituitary. Here the follicle stimulating (FSH) and leuteinizing hormones (LH) are produced which also seep into the bloodstream.

When these hormones reach a certain level in the ovary, they stimulate 1 of the 100's of yolks to start a 10-day period of rapid growth; the next day a second yolk starts enlarging. Consequently, a new egg starts to grow rapidly each day for 3 to 5 days followed by a day missed before another yolk starts to develop. The number of days of the clutch is determined by both genetic and environmental effects. At the time the yolk reaches its normal size it is ready for ovulation. This occurs about 7 hr before it is destined to start down the long path of packaging so it can break out of the follicle. Ovulation also is programmed in a similar manner as that required for rapid yolk growth. The hormone which sets the time fuse is leuteinizing hormone (LH) from the pituitary. The laying of the egg and ovulation of the next yolk are programmed in a linear sequence about 15 min apart, even though one is not dependent on the other. During this

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[1]So-called circadian rhythms are about 24 hr in length and are related to (but not necessarily governed by) the daily flux of events that derive from the earth's rotation. Features in the lives of birds that have a circadian rhythm include body temperature changes, general activity, ovulation and incubation, as well as feeding of self and young

period the bird changes in physical appearance—she eats voraciously and gains weight gaining from ½ to 1 lb in 2 to 4 weeks and her comb enlarges and reddens. Some of these changes are masculine, although predominantly feminine. She is off the roost at the crack of dawn and scratches in her yard even though she does not need to do so. The interstitial cells of the cortex of the ovary in close proximity to the developing yolk produce a chemical known as alpha estradiol, an estrogen or feminizing hormone. At the same time in the medulla of the ovary, a second path is programmed to interstitial cells which secrete testosterone, a masculinizing hormone. Both hormones seep into the bloodstream and make remarkable changes internally. The pubic bones spread so that when the bird starts to lay, the egg can slip between her bones readily. The oviduct enlarges rapidly in preparation for production. Metabolic rate, adrenal function, and calcium level in the blood are all programmed together so that in ten days egg production is in full swing.

At ovulation, the egg drops free into the body cavity where it is immediately picked up by the funnel of the oviduct. The mechanism of production is such that no hen can produce 2 eggs less than 22 to 23 hr apart. Egg-type hens require 24 to 25 hr to place the membranes and shell on each egg. Ovulation for the first egg of a clutch occurs just after lights are turned on. Thus, the hen is not a self-starter—she must have a rhythm or beat on which she can rely and this comes from her environment. Stresses like crowding, feed restriction, social rank, fighting, cold, heat, and others can interrupt the hen's egg production.

HORMONES

The term "hormone" was created by two British physiologists, Davis and Starling in 1903 from the Greek word "hormao" which means "I excite." Hormones are excitatory in their action and often referred to as a chemical messenger. Sex behavior and instincts depend upon specific hormone secretions elaborated by the respective reproductive glands. The most obvious external effects are seen in the comb, wattles, and plumage in male and female birds. A most curious fact is that there exists a dual potentiality of the sexes—all males and females combine potentialities of either sex. In the hen, a preponderance of female hormone is secreted by the ovary; in the cock, the male hormone predominates. Under certain conditions as in disease or castration, balance between the male and female hormones becomes disturbed or one or the other is completely repressed. When castration is performed upon young cockerels, secondary sex characters and sex instincts are suppressed. Body weight is greater than that of uncastrated males of the same age. Old males are fattened and their muscles made tender by administration of estrogen.

Since estrogen has a feminizing effect, it could have a very undesirable effect upon persons eating the chicken if it remains in the dressed bird. Regulatory agencies are responsible for seeing that the residual estrogen remaining in the dressed carcass is of sufficiently low level to be harmless to humans or they will not permit the product to be sold.

Hormones give poultrymen control over the timing of egg production. A large dose of progesterone makes hens quit laying on the day of injection, but production is back to normal four weeks afterwards. Most of the birds molt completely; the rest lose about half of their feathers. This injection forces birds out of production when egg prices are low and allows them to come into heavy production when egg prices rise. Progesterone is an effective and harmless way of molting chickens because they maintain their body weight during the molt better than chickens force-molted by other methods.

Heritability of thyroid weight has been shown through breeding and selection. Calcitonin or thyrocalcitonin, a hormone in the ultimobranchial rather than thyroid, has an important function in regulating the level of calcium in body fluids. The anterior pituitary controls growth; too little pituitary hormone produces dwarfs and too much, giants.

Drugs such as sulfocyanide, thiourea, and thiouracil inhibit the formation and secretion of thyroid hormone and thus are powerful goitrogenic compounds. In chickens, addition of thiouracil to chicken rations at levels up to 0.2% of the ration consistently improves carcass quality in broilers. In most cases, however, thiouracil decreases the rate of growth.

Hormonizing by estrogens was first introduced to the poultry industry in 1947 by injection of pellets of hormone. Pellets are absorbed very slowly and harmful amounts of the hormone are not found in edible portions of the bird. Birds are implanted by means of a simple device—an implanter which holds a number of pellets in clip form. One pellet is injected under the loose skin of the neck next to the head. An experienced operator with 4 people to catch birds can implant as many as 1,500 birds per hour. If the litter becomes too wet, which often happens with hormonized birds, a low protein diet is one method of cutting down excess dampness. A 16 to 17% protein feed is used by most growers to minimize the problem, although some start on a 14% protein diet from 4 to 5 days before implanting, and carry the same diet through to marketing time. Plenty of water is made available after caponizing.

Cabbage seed, rapeseed, and steamed black or white mustard seed all produce pronounced thyroid enlargement. These plants belong to the mustard family Brassicaceae Cruciferae. Plants other than Cruciferae also cause development of goiter—for example, raw soybeans and a variety of chemical materials. Thiocyanate and related monovalent anions in-

hibit the concentration of inorganic iodide ions in the thyroid and thus decrease the formation of the thyroid hormone. Certain plants which contain antithyroid compounds in their edible parts have goitrogenic materials as inactive thioglucoside precursors. These thioglucosides are hydrolyzed enzymatically to liberate the active aglycone. Other antithyroid substances such as the thiocyanates are present in certain feeds, but their goitrogenicity is overcome by the addition of iodine to the diet.

All of the hormones discussed are classed technically as drugs and as such come under the provision of the Food and Drug laws. Consequently, before any of them can be obtained for general use, the U.S. Government officials must be sure that their use will not cause a health hazard to consumers of the poultry. The current status of the acceptability of hormones and related chemical substances should be cleared through State and Federal feed control officials before being used.

In the case of thyroprotein, approval has been given for its use in poultry feeds. No evidence so far has been found that the hormone residues will be found in the flesh or eggs of birds that would ultimately affect the consumer. The goitrogenic drugs, thiouracil, etc., are still restricted and so cannot be used for fattening, except under carefully supervised conditions.

The female sex hormones were formerly released for use conditionally providing the pellets are removed before the carcass of the bird is marketed. There still may be some question as to the advisability of using these compounds, however, because recent research has shown that traces of estrogenic compounds are retained in the fat storage depots of the body for considerable periods of time. It is evident that under any circumstances, hormone therapy must be controlled very carefully in order to obtain uniformly good results and protect consumers.

Endocrine glands act as a complicated set of delicate controls over many vital body processes. The endocrine glands include: pituitary located at the base of the brain; pineal also in the brain; thyroid, parathyroid, ultimobranchial body, and thymus (not considered by some to be endocrine) located in the neck; adrenals in the abdominal cavity near each kidney; pancreas also in the abdominal cavity; and testes in the male and ovaries in the female. The secretions of these glands are emptied directly into the blood vessels within themselves. That is why they are known as ductless glands or glands of internal secretions. Each gland secretes one or more substances called hormones in very minute quantity and normally formed as needed through nervous impulse. Hormones control sexual growth and the various stages of reproduction.

The thyroid gland through its hormones, thyroxine and triiodothyronine, controls the rate of activity of most metabolic functions in birds. It is concerned with body growth, feather development, and egg production—in

short, practically all functions that are of economic importance in the poultry industry. Chemically, thyroxine is a derivative of the amino acid, tyrosine, formed in the thyroid gland by reaction between tyrosine and iodine. The production of thyroxine is under the influence of the pituitary gland which, in turn, is influenced by many environmental factors such as light, temperature, and stress. The hormone is distributed through the blood to all cells of the body.

Thyroxine-like compounds produced commercially by the addition of iodine to casein have many of the benefits of thyroxine. A product "Protamone" is effective in improving growth, feathers, and carcass composition in market ducks, especially during the hot summer months. In summer, feathering is poor and ducks tend to lay on excessive amounts of fat. Protamone also improves the feathering of growing turkeys but not growth rate.

Hormones regulate the metabolism of protein, fat, and carbohydrate, and thus it is important to understand these substances in the study of nutrition. It is logical to assume that many if not most of the actions of nutrition on reproduction are mediated through altering hormone production by the endocrine glands. Endocrine imbalances also increase requirements for dietary factors necessary for growth and reproduction. The only type of malnutrition which has been conclusively proven to impair the secretion of gonadotropic hormones by the pituitary is underfeeding or any state leading to inanition, including inadequacies of the B-vitamins. Thyroid function also is decreased by undernutrition via the pituitary. But in addition it can be depressed directly by lack of iodine or the presence of goitrogenic substances in the diet. There is considerable basis for the belief that the gonads and sexual activities are more easily impaired during inanition than other body functions.

Hormonal imbalances may impair reproductive activities by several means. Hypo- or hyperthyroidism reduces the secretion of gonadotropic hormones by the pituitary, alters gonadal response by gonadotropins, and changes dietary requirements. Hyperthyroidism prevents conversion of carotenes to vitamin A.

The pituitary gland is unquestionably the master gland of the body. It consists of two parts—a larger anterior lobe and a smaller posterior lobe. It is located in the bony cavity at the base of the brain surrounded by a rich supply of blood vessels. The development of such sex characteristics as body conformation and, in the female, the ripening of the ovum in the ovary is directly or indirectly the result of stimulation by hormones secreted by the anterior lobe of the pituitary gland.

Carbohydrate metabolism is influenced by a hormone secreted by the pituitary. Digestion and assimilation of fats and proteins are influenced by

anterior pituitary hormones as is secretion of insulin by the pancreas. Some forms of obesity are attributed to glandular disfunctions.

The posterior lobe of the pituitary stores and releases the hormone, pituitrin. The kidneys are influenced directly by the posterior lobe through the stimulation of the filtering mechanism. The testis has two major functions—production of spermatozoa and the secretion of the male hormone, testosterone. It is antagonistic to the female hormone, estrogen, which induces female characteristics. It even produces male characteristics in females. Testosterone has been isolated, analyzed, and synthesized so it is available in pure form.

The ovary is a reproductive gland of the mature female and is located on the left side of the body in the abdominal cavity connected to the uterus by a tube which serves for passage of the egg. Its functions are the production of the egg as well as the follicle which secretes the hormone, estrogen, and the hormone, progesterone. Estrogen has been analyzed chemically and prepared synthetically. It induces the development of secondary sex characteristics in the female, such as distinctive plumage, and inhibits the pituitary from secreting the follicle-stimulating principle.

The parathyroids are 2 to 4 ductless glands located under each lobe of the thyroid gland. Parathormone, produced by the parathyroids maintains equilibrium between the soluble calcium and phosphorus compounds in the skeleton and the blood.

The adrenal glands are located in front of each kidney and consist of two parts: the medullary (inner) and cortical (outer) portions. The hormone, adrenin, is secreted by the medullary part and the hormone, cortin, is contained in the cortical portion of the gland. The latter is similar to testosterone in chemical makeup and its antagonistic reaction to estrogen.

The thyroid gland resembles a tiny shield and is located on either side of the upper part of the windpipe. Chemical analysis shows that thyroxine contains large amounts of iodine. An increased production of thyroxine gives individuals an excessive amount of energy (metabolic rate may be doubled), whereas a decrease makes individuals sluggish. A deficiency of iodine in the diet results in a decreased functioning of the thyroid gland.

In poultry husbandry, it has been common practice to castrate males to improve the tenderness and tastiness of the meat. As previously stated, an estrogen is a substance or hormone normally produced by the ovary of a mature fowl. Substances that have the same effect as the natural hormone have been made synthetically. They are used in commercial hormonization of poultry, a logical successor to caponization which it resembles in some respect. Caponization is the surgical removal of the sex organs; whereas, hormonization is the addition of a hormone which produces extensive depression of the size and function of the testes—an effect that has

given rise to the common misnomer for treated birds: "Chemical Capons" or "Caponettes."

Estrogen produces numerous effects on birds; some have considerable significance from a commercial viewpoint. Hormonization rapidly increases the cholesterol, phospholipid, triglyceride, and protein contents in the blood. The percentage volume of red cells is decreased. Estrogen causes hyperossification of endosteal bone which causes fragile bones, but which have a normal percentage of ash. The birds' combs shrink and become pale, wrinkled, and nonwaxy. The masculine sex drive is lost, aggressiveness diminishes, fighting, and crowing cease. Males squat when approached and spermatogenesis ceases.

Turkeys respond similarly to chickens in regression of head furnishings and diminished fighting instinct, but in this species there is heightened sexual activity. The ovary is quite resistant to estrogen treatment and there is no reduction in egg production. Estrogen produces an enlargement of the vent and spreading of the pubic bones such as normally occurs in laying chickens. A single injection of estrogen interrupts broodiness in hens and returns the birds to egg production. Feather growth is stimulated and the development of new pin feathers inhibited by estrogens. This effect is more marked in turkeys than in chickens. Improved skin texture is a consequence of estrogen treatment, presumably due to hypertrophy of the epidermal strata.

Diethylstilbestrol was the first compound used commercially subcutaneously implanted as pellets in the neck of the birds. Effects are noticeable within a week, but require weeks for satisfactory results. A paste suspension containing diethylstilbestrol is also used for implantation. Attempts were made early to feed diethylstilbestrol but early results were unsatisfactory. Results led to a search for new compounds of greater potency by the oral route. Dienestrol diacetate in the feed has given good results and

TABLE 8.3

DIENESTROL DIACETATE TREATMENT PERIODS: WITHDRAW 48 HR BEFORE SLAUGHTER

Type of Birds	Age at Start of Treatment	Lipamone[1] Lb (Dienestrol Diacetate) per Ton Feed	Feeding Period
	(Weeks)		(Weeks)
Broilers	5 or 6	1/3	4 to 6
Broilers	3	1	3
Roasters	5 or 6	1/3	6 to 10
Roasters	8 or 9	1/2	5 to 7
Turkey broilers	8 to 10	1	3

[1]American Scientific Laboratories, Bloomfield, N. J.

TABLE 8.4

FEEDING PROGRAM DURING TREATMENT OF BIRDS WITH ESTROGEN PELLETS

Type of Birds	4-5 Days Before Treatment	After Treatment
Small broilers	Small amt. of corn	10 to 25% corn to market
Broilers		
Ration 20–22%	Feed up to 50% corn	Up to 50% corn to market
Ration 17–18%	Feed up to 40% corn	Up to 40% corn to market
Broiler	4½ parts concentrate, 38% to 15½ parts of corn	Same schedule to market
Caponette roasters	Up to 50% corn	To market (these birds are shot again 2½ wk after first shot; increase corn if desired after 2nd shot)
Stags	Free choice	To market (2nd shot 2½ wk after first); free choice
Cull hens	Free choice	Market in 3 wk

is used commercially (Table 8.3 and 8.4). A moderately increased rate of fat deposition is obtained by feeding this compound. Turkeys fatten less dramatically than chickens in the response to estrogens. Oral administration of estrogens to turkey has led to some unfavorable results although the average market grade of turkey broilers is improved.

Estrogen treatment has at least some influence on each of the components of carcass quality and for the most part the influence is favorable. Fatness is the best advantage; extra subcutaneous fat improves the finish of the dressed carcass. Muscle and leg fat increases and improves the "juiciness" of the meat, lightens flesh color, and increases tenderness. Flavor evaluation is inconclusive and inconsistent. Stability of meat in storage is unaffected. Blemishes due to fighting are decreased in chickens but not in turkeys. A smooth, silky texture is imparted to dressed carcasses. Skin tenderness is increased and, therefore, extra care is necessary during scalding and plucking. Extra care in processing is also necessary because of increased bone fragility.

Extent of effects on carcass quality depends on the length of the treatment with estrogen, its route of administration, and the age of bird at time of treatment. Estrogen mixed in the feed at moderate dosages increases feed intake, but has no effect on rate of gain of growing birds. There may be a slight growth depression with turkeys.

Kafir, wheat, and corn are superior to oats and barley in fattening rations containing estrogen. High density mashes also improve rate of gain, feed efficiency, and finish of the dressed carcasses, and average grades are as good as those observed in birds treated with estrogen regardless of the ration.

Some bad features of estrogen treatment sometimes occur. Repeated implantations of pellets produce severe atheromatous lesions in cocks.

Treated birds sometimes go "off feed" and make subnormal gains during hot weather and react with more than usual severity to disease. Exceptionally moist droppings may result. Estrogen treatment of poultry is not permitted in Canada but pellets were permitted in the United States for a number of years, although now the practice is not approved by the Food and Drug Administration.

To recapitulate, finishing quality in all classes of meat chickens, except mature hens is improved by estrogen treatment. Slight increases in weight gains are obtained in chickens, along with an increase in feed consumption and feed efficiency. Estrogen treatments of turkeys are less useful than for chickens, being most advantageous for finishing immature birds. Turkeys fatten less dramatically than chickens but other effects such as feathering are improved as much or more. Diethylstilbestrol is usually implanted as pellets or paste in the neck at the base of the skull, but is no longer permitted by the Food and Drug Administration. Offal from estrogen-treated birds should not be used for animal feeds. Dienestrol diacetate is used commercially in the feed for low-cost superior quality broiler and roaster production.

ENZYMES

Enzymes are organic substances produced by living cells possessing the ability to catalyze specific chemical reactions. They synthesize or break down chemical compounds or transform them from one type to another. They are highly specific and catalyze only one reaction or even act upon only one isomer of a particular compound. There may be many different enzymes in a single cell. The number of known enzymes is around 750 of which 100 have been isolated in crystalline form. All enzymes are conjugated proteins. Many have traces of Zn, Co, and Cu which stay with the protein even in crystalline form.

Enzymes go back to the earliest written documents of human activities. Housewives used leaven for making bread, calf stomachs for curdling milk to make cheese, fermentation with microorganisms to produce wine, beer, and medicinals, tanned leather, etc. There is large scale production of enzymes called industrial enzymes for specific uses in the food and chemical industry.

The most general way for naming enzymes is to add the suffix "-ase" to the name of the medium on which the enzymes work. For example, "maltase" hydrolyzes maltose. Another way is to add the suffix "-in" to the name of the source from which it is produced. Papain is produced from the plant papaya, ficin from the plant ficus, and pancreatin from pancreas. A third manner of naming enzymes is to add the suffix "-ase" to the reaction the enzyme catalyzes. For example, "invertase" inverts sucrose to glucose and fructose.

The animal's own enzymes in its digestive tract digest or break down proteins, carbohydrates, and fats in feeds to simpler materials before they are used by the animal for energy and growth. Supplemental enzymes in the feed are sometimes used to augment the animal's own supply of digestive enzymes to enable it to utilize feeds more rapidly and efficiently. This is particularly true of grains with poor feeding value. For example, Washington State University researchers in 1957 showed that the feeding value of Pacific Northwest barley for chicks and poults could be upgraded to approximately equal that of corn by either water treatment or enzyme supplementation. Both bacterial and fungal enzyme preparations are effective although the bacterial products are more economical.

Enzyme-containing materials as feed additives are not new and early reports indicated that they were of doubtful value. The general conclusion was that the digestive tract of a normal animal is not deficient in the enzyme required for the digestion of rations usually fed to those animals. The recent advent of high energy feeds with increased emphasis on feeding for faster growth and improved feed efficiency of poorly digested grains has stimulated interest in taking another look. Recent work indicates that under certain conditions enzymes may have some value as feed additives. Their future would seem to depend on products standardized with respect to the content of the specific enzyme for increasing the availability of a specific substance in the ration. So, it remains to be seen whether such products can be supplied at a price permitting possible use in feeds.

Beneficial effects of enzyme treatment have been improvement in growth, feed utilization, and litter condition. Northwest barley substituted for corn in an ordinary chick or turkey ration depresses growth and feed conversion by 20%. Wet litter problems occur when barley is used in place of corn, due to increased water consumption. The addition of enzymes to feed lowers water consumption and the water content of the manure appreciably. This is of practical importance to the poultryman. Barleys grown in the Midwest and East do not respond to enzymes as do those grown in the Rocky Mountain and Pacific coastal states and Western Canada. Rye and oats are also markedly improved by enzymes; wheat is improved to some extent. Some benefits with corn and milo have been obtained.

Results with enzyme treatment of feeds with laying hens are less clear-cut; some improvement in egg production, feed efficiency, and hatchability are claimed. In general, there is a greater response from both feed and growth efficiency by water treatment than by enzyme preparation.

Enzymes are organic catalysts that by their mere presence in trace amounts initiate or accelerate the speed of reactions occurring in organic matter that would not otherwise proceed at an appreciable rate. Enzymes

catalyze all the chemical changes occurring in living plants and animals. Enzymes are very sensitive to the temperature and pH of the medium in which they operate. Temperatures of maximum activity usually fall within the range of 86°-122°F. Above the optimum temperature, they are permanently inactivated; lower than optimum, they become inactive but regain their activity when warmed. Optimum pH varies from neutrality to decidedly acid.

Chemical changes induced by enzymes are gradual step-by-step processes, not marked by severe energy changes. Conversion of starch into glucose is the end result of several intermediate changes, each requiring a different enzyme. Some enzymes are secreted in both active and inactive forms. The inactive form becomes active only in the presence of some other substance such as a trace metal, a vitamin, or a complex protein compound. Living cells are not essential for enzymatic action; enzymes can be separated from the cells without loss of catalytic activity.

BONE FORMATION

Calcium and phosphorus are required for normal bone formation. Normal bone is formed in two ways: (1) the direct development of so-called "intramembranous bone;" and (2) a more complicated process involving growth, maturation, and calcification of a cartilaginous model, followed by gradual removal as true bone is deposited. All bone is formed by the action of osteoblasts. These cells are responsible for the formation of bone matrix (osteoid) which is composed mainly of cartilaginous fibers and the cement substance. Calcification of the matrix follows. As the bone matures and full calcification takes place, the cell processes withdraw from the canaliculi and the osteosites undergo slight shrinkage leaving an anastomosing network of tiny passages which conduct nutrients from the capillaries to all parts of the bone. Most of the increase in length of long bones is by interstitial growth within the epithelial cartilage.

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Metabolism

PART 1 Digestion

INTRODUCTION

Metabolism consists of all chemical changes which nutrients undergo from the time they are absorbed into the body until they appear as excretory products. It includes the distribution of the absorbed food—building (anabolism) and breaking down (catabolism) of tissues as well as absorption and release of energy. Digestion is a disintegration of the feedstuffs into simple nutrients into the gastrointestinal tract in order to prepare them for absorption. Feed is picked up by the beak of the chicken, moistened with saliva, and swallowed without mastication. It passes down the gullet to the crop where it is stored until it can be ground, mixed with digestive juices and digested.

In the crop, the feed is softened by the ingested water and liquid secretions from the lining of the inner crop wall. The crop contents have a slightly acid reaction due to formation of lactic acid. A crop filled with whole grains is emptied slower than one filled with ground grains. Feed moves from the crop, a small quantity at a time, into the gizzard. Rhythmic contractions of the walls of the intestinal tract force the feed along. When the feed enters the proventriculus, it stimulates the glandular cells to secrete gastric juice, a pepsin-hydrochloric acid mixture used for the digestion of proteins and dissolving minerals. The feed is thoroughly macerated in the gizzard being squeezed between and rubbed over the rough lining of the walls. Softened grains are easily macerated and pulverized. Grit aids in this process but is not absolutely essential.

As the ground feed enters the duodenal loop, pancreatic juice from the pancreas and alkaline bile salts produced in the liver and stored in the gall bladder are secreted. The bile salts neutralize the acidity of the contents. The pancreatic juice supplies amylase which breaks down starch into disaccharides which are further hydrolyzed into simple sugars (glucose). The chicken's intestinal tract is short and the passage of food rapid, so that bacteria have little time to work on complex carbohydrates. The fats of the feed are emulsified by bile salts and acted upon by the enzyme, lipase, from the pancreatic juice. The fats are digested into fatty acids and glycerol, the end products of fat digestion.

As the food is ground and mixed in the gizzard with the pepsin-hydro-

chloric acid mixture, the proteins are broken down into less complex proteoses and peptones. Trypsin from the pancreatic juice breaks down some of these into still simpler products, amino acids. Erepsin secreted in the small intestine completes the digestion of the protein products into amino acids. Minerals are dissolved rather than digested and changed from solid to liquid in the gizzard. Digestion is rapid in poultry, taking about 2½ hr in a laying hen but much slower in birds out of production.

The digested nutrients pass through the intestinal wall into the bloodstream. Absorption takes place and is greatly increased by the presence of innumerable villi or finger-like projections. Within each villus is a lacteal and a network of capillaries of the blood system. Digested nutrients in the form of simple sugars, amino acids, and dissolved minerals pass through the wall surface into the blood capillaries. Digested fats pass through the intestinal wall into the lacteals of the lymphatic system and form neutral fats. The fats pass along with the lymph and enter the venous bloodstream near the heart. The blood transports the absorbed food nutrients to the liver. As they pass through the capillaries of the liver most of the glucose is transformed into glycogen for storage.

Some amino acids are deaminized as they pass through the liver. Carbohydrate is made available for heat and energy, and nitrogenous fractions are transported to the kidneys for elimination. Many impurities absorbed from the intestinal tract are retained by the liver cells as the blood passes through its capillaries. For example, absorbed poisons are usually found in the liver. The blood carrying the digested nutrients passes from the liver by way of the hepatic and postcaval veins to the heart and lungs where carbon dioxide and water are given off and oxygen taken on. The blood is returned from the lungs to the heart and then pumped through the arteries to all tissues of the body.

Digested nutrients pass from the capillaries to the lymph which bathe the tissue cells. Glucose is burned in the cells for heat and energy to produce carbon dioxide and water. Excess carbohydrates are transformed into body and egg fats. Fats are gradually removed from the bloodstream and stored as adipose tissue and serve as a reserve of heat and energy. Amino acids absorbed into the bloodstream are used to build new body tissues or rebuild wornout tissue. An excess is used for energy and heat or transformed into fat. Minerals absorbed from the bloodstream are transformed to bone, egg shell, or used in soft tissues. There is some storage of excess minerals but most are excreted. Vitamins are stored in the liver and other tissues. There is a greater storage of fat-soluble than water-soluble vitamins.

In poultry, the urine is not stored in a bladder but is poured into the cloaca in contact with the feces. Urine is excreted as a solution of uric acid, whereas in mammals it is excreted as urea. Poultry digest fiber in the ceca

but only to a very limited extent. Cooking increases the digestibility of some of the nutrients, particularly starch. It takes from 50 to 70 hr to clear the digestive tract of corn compared to twice that time for wheat, barley, and oats.

Absorption of nutrients takes place largely in the small intestine. Carbon dioxide and water in the form of vapor are excreted from the lungs. Water, ammonia, and minerals are lost through the urine. The remainder of the body waste is excreted in the feces.

WATER METABOLISM

Water is necessary for life. Even the embryo is protected by water. The bird obtains its water from three sources: (1) that which is consumed by drinking, that is, "free" water; (2) the water that is contained in the feed eaten; (3) that made available through metabolic processes in the tissues. This latter is called "metabolic" water. Thus, there is free water, feed water, and metabolic water. Metabolic water comes from oxidized food—1 lb of starch yields approximately 0.56 lb of water upon being metabolized; 1 lb of fat yields 1.07 lb of water, and 1 lb of protein yields 0.40 lb of water. For a chicken to be in water balance, water requirement must equal water loss.

Water requirement should not be confused with water consumption. They are not the same. The bird requires more water than it consumes. This it gets from metabolized water and food water. The chicken does not sweat but it does lose water by evaporation through the skin and a great deal through respiration. The other loss of water in birds is through excretion and by egg production as well.

Some approximate values from water balance figures:

Water from	Pullet	Layer
	Gm	Gm
Feed consumption	85	100
H_2O intake	145	300
Feces and urinary	90	195
Respiratory	35	35
Egg	None	35
Loss	−20	−10

The more feed a chicken consumes, the more water is taken. Seventy-three percent of muscle is water; the more fat, the lower the water. Body water can be calculated by use of chemicals or radioisotopes. These materials are injected into the blood stream. It takes a chicken about 21 min for the complete mixing of the injected material with all the body water. The metabolism of water by the chicken is rapid. The one-half life of water in the body is three days in the laying female and in males about nine days.

TABLE 9.1

FEED AND WATER CONSUMPTION OF GROWING WHITE LEGHORN FEMALES

Age in Wk.	No. of Birds	Mean Chick Weight (Gm)	Feed Consumption (Gm per Chick per Day)	Water Consumption (Ml per Chick per Day)	Ml Water Consumed per Gm Feed
1	108	71.9 ± 9.3[1]	10 4 ± 1.2	26.6 ± 5.2	2.6
2	96	102.8 ± 14.7	16.9 ± 2.0	39.8 ± 7.6	2.4
3	66	153 5 ± 18.9	20.5 ± 1.8	52.6 ± 9.4	2.6
4	74	250 2 ± 32 4	32.8 ± 4.8	75.9 ± 14.5	2.3
6	50	384.5 ± 45.6	38.8 ± 7.4	80.0 ± 23.7	2.1
8	40	578.3 ± 39.0	49.5 ± 6.0	116.5 ± 30.6	2.4
16	20	1,293.4 ± 138.2	75.5 ± 20.7	165.6 ± 49.8	2.2
32	20	2,035.2 ± 199 6	136.2 ± 27.9	483.5 ± 129.9	3.6

[1]Standard deviation

TABLE 9.2

TOTAL DAILY WATER LOSS OF WHITE LEGHORN FEMALES

Age (Wk)	No. of Birds	Water Outgo (Gm per Bird per Day)			Total Daily Water Loss (Gm per Bird)
		Excrement	Evaporation	Eggs	
1	108	16.6	3.3	. .	20.0
2	96	23.0	6.2	. . .	29.2
3	66	29.0	9.2	. . .	38.2
4	74	41.0	13.3	. .	54.2
6	50	46.2	19.1	. . .	65.3
8	40	71.3	24 8	. .	96.1
16	20	91.9	46.1	. .	137.9
32	20	319 2	53.0	34.7	406.9

Metabolic water is generated by body processes involved in the production of energy. Ten to fifteen grams of water are produced by the oxidation process whereby each 100 Cal of energy are produced by the body. A typical diet supplying 2,500 Cal supplies 250 gm of water daily. Each gram of fat burned for energy produces twice as much water as a gram of protein or carbohydrate.

Substantial amounts of heat are removed from the birds by means of expired water vapor from the lungs. When deprived of water chickens seek shade or reduce activities, which also conserves water. In times of stress or reduced intake, poultry have the ability to conserve water and maintain a proper balance of critical fluids. Several hormones act when necessary; most important is the diuretic hormone secreted by the pituitary gland. This hormone reduces the output of urine to conserve water. Normal water losses are a part of such essential body functions as breathing, excreting,

sweating, and evaporation from the skin. Excessive water losses leading to dehydration may occur from prolonged diarrhea, vomiting, loss of blood, hemorrhaging, severe burns, and fever.

TABLE 9.3

WATER BALANCE OF GROWING WHITE LEGHORN FEMALES

Age (Wk)	Mean Chick Weight (Gm)	Total Daily Intake (Ml per Bird)	Total Daily Outgo (Mg per Bird)	Balance
1	61.9	27.5	20.0	7.6
2	102.8	41.3	29.2	12.1
3	153.5	54.5	38.2	16.3
4	250.2	78.9	54.2	24.6
6	384.4	83.5	65.3	18.2
8	578.3	121.0	96.1	24.9
16	1293.4	173.4	137.9	35.5
32	2035.2	495.9	406.9	89.1

PART 2 Grit

INTRODUCTION

In the absence of teeth in poultry, the gizzard carries out the process of grinding feed for digestion and assimilation with grit used as a grinding agent. Birds permitted to forage instinctively consume large amounts of gravel. However, chicks can be raised without grit and health appears to be normal. Grit helps develop thickly lined gizzards. Confined birds and those fed large quantities of fibrous feeds need grit to break down the tough indigestible feed particles for more complete assimilation. Some plant nutrients in feeds are surrounded by indigestible cellulose capsules. Unless these encased nutrients come in contact with the digestive juices they are wasted. The finer the feed is ground, the closer is the contact between digestive juices and feed particles, and the more thorough digestion becomes.

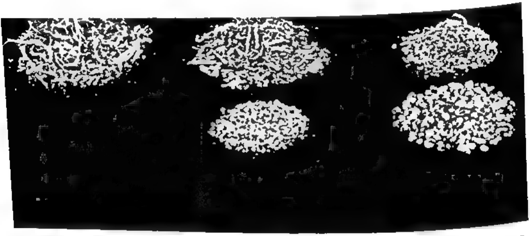

FIG 9.1 CONTENTS FROM 3 GIZZARDS OF LEGHORN-TYPE PULLETS AT 22 WEEKS OF AGE (LEFT) NO GRIT, (CENTER) WRONG SIZE GRIT, AND (RIGHT) CORRECT SIZE GRIT

KINDS OF GRIT

Oyster shells, clam shells, coquina shells, and amorphous limestones are considered soft, soluble, and calcareous. These supply calcium as well as grinding material but have a comparatively short life as effective grinding material. Local supplies of river gravel and pebbles which are largely quartz have been used satisfactorily as hard, insoluble grits.

Fryers consume about two-thirds lb of grit to market time; pullets less than 1 lb to laying time. Layers consume ¼ lb per bird per month, somewhat more with heavy grain and range feeding. For laying hens provide one 4-ft hopper for each 100 birds; for broilers, 1-ft of grit hopper space for 300 birds. Place grit hoppers close to the feed.

Where hard or fibrous feeds are used, poultrymen agree that grit is particularly valuable. With all-mash, finely ground rations, there is a difference of opinion among investigators. Some record small benefits; others none.

In processing hard grit from quarries, only layers of certain quality are acceptable to make grit. Small charges of dynamite are placed in strategic positions and air pressure is forced through to lift the ledge from its base. Huge granite blocks removed from the ledges are taken to processing plants and tossed into the crusher. From the crushers the broken granite is carried on an endless belt to vibrating screens or sifters. Each screen separates a different sized grit. Fine particles are used for such birds as canaries, a slightly coarser grit for chicks, another coarser for poults, another for hens, and a fifth for turkeys. Much grit is produced in Georgia and in North Carolina and shipped all over the United States.

Chicks are fed chick-size grit along with their first food. When four weeks old, growing size grit is kept in hoppers before them. Pullets and hens are fed hen-size grit, changing to hen size when the poults are four weeks old. Hen size grit is kept before them while on range during the growing period. Turkey size grit is fed to adult turkeys during fall season and also to breeding stock at all times. Oyster shell does two jobs at one time. It provides extra hard grinding surfaces for breaking down the feeds and supplies calcium for bone and egg shell. Some poultrymen use plenty of hanging-type grit hoppers, 1 to each watering station for 3,000 to 4,000 birds.

Grit can also be provided weekly or every 2 weeks by sprinkling it on top of the feed or mixing 1 to 2% of the grit into the feed one day a week. Whole-beaked pullets consume more grit than debeaked birds which have tender bills and will eat more if it is mixed in the feed.

A well-developed gizzard is indicative of a well-developed digestive system. Good feeding produces gizzards weighing 10% more than those from birds fed high fiber feeds without grit. Grit feeding grinds feathers and litter and makes more room for more valuable feed. It prevents gizzard impaction and keeps the intestinal tract clear.

No matter what the source, grit is relatively inexpensive and if properly used gives returns far beyond its cost. The grit content of the gizzards of birds which have received no grit during the laying period gradually declines from a mean of 10.7 gm a bird at housing to 1.9 gm per bird after 336 days.

In summary, grit is not essential but it is desirable from the point of view of efficient utilization of feed materials and the maintenance of the normality of the digestive tract. There is ample experimental evidence available to indicate the need for grit when poultry are fed whole grains and coarse feeds. But where all-mash rations are fed, the information is controversial.

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Components of the Ration

PART 1 Introduction

Cereals are very starchy. Oil seeds have a predominance of glycerides. Fruits contain sugar, spices owe their value to terpenes and related substances. Many seeds are separated mechanically into parts which have definite chemical characteristics.

Some knowledge of the structure and morphological details of different feedstuffs is desirable. For example, seeds consist of a seed coat or spermoderm, perisperm, endosperm, and embryo or germ. The last two are formed within the embryo sac. Perisperm, endosperm, and embryo differ greatly in their relative size and development. But all contain certain reserve materials for nourishment of plants. In cereals, the reserve material is largely in the endosperm, in rape and most legumes, in the embryo. In flax seed, it is divided between the endosperm and embryo.

Stems and roots show in cross sections several zones—epiderm, cortex, and the central cylinder with its fibrovascular bundle. Leaves show between epidermal layers the green tissues that take part in photosynthesis. The definitions of the more important tissues are given in the glossary and may prove helpful to those unfamiliar with the terminology of the histologist.

The six so-called crude constituents of feeds are: water, fat, protein, nitrogen-free extract, fiber, and ash. Each contains numerous actual chemical constituents. The term crude is commonly applied only to fiber but all groups are crude with the nitrogen-free-extract (NFE) being crudest of all.

There is more to feeding the birds than just a knowledge of feed composition. Poultry differ from other animals, so much must be known about the physiology of the birds.

Concentrated feeds have increased considerably in use over the years, particularly with respect to complete feeds. Much of this is due to the increase in population but other factors are also involved. Poultrymen find their time is more valuable in working with the birds than it is mixing feed, especially when he can get competent specialists to do this job. Hence, they are buying more manufactured feeds.

There are some areas in the country where they depend upon the pasturage. This reduces the amount of feed that goes through the feed mills. The central United States has more chickens and produces more eggs than

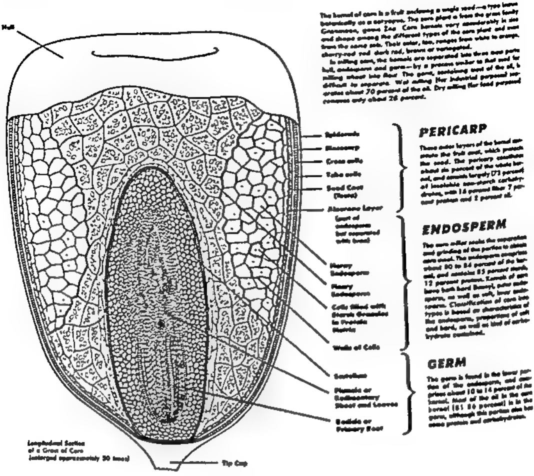

FIG 10 1. STRUCTURE OF A KERNEL OF CORN (MAIZE)

the others. On the other hand, the Southeast is way out in front with broiler production. The central states, particularly Minnesota are important for turkey production. Chickens and turkeys do a very fine conversion job in the production of meat.

ENERGY

Energy is produced by the metabolism of carbohydrates, fats, and proteins. It is discussed with the nutrients because there are intimate relationships with other nutrients. If feedstuffs were burned in a bomb calorimeter, and the amount of heat measured, one could calculate the gross energy. However, poultry do not get this much energy from the feed because some is digested and some is not. That which is not digested is excreted as indigestible residues (feces). The latter is burned in a bomb calorimeter to determine how much heat would be lost to the animal. What is used by the animal is digestible energy, part of which is used in the production of eggs and meat, but some is excreted by the way of the urine.

What is actually used by the animal for energy purposes is the metabolizable energy. However, there is a cost to the animal in the utilization of this energy; this is called the specific dynamic effect. The combustion of protein provides extra heat which is the result of specific dynamic action. That which is left after all these losses goes into productive use and is called the net energy or productive energy.

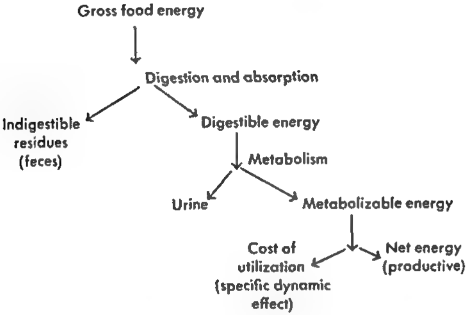

FIG. 10.2. ENERGY RELATIONSHIPS

With poultry it is difficult to determine energy values. Recently, metabolizable energy has been used in comparing feeds. In the first place, M.E. (metabolizable energy) values are more constant than P.E. (productive energy) values. Gross energy values would not be an accurate index if the material was poorly digested.

Corn is rather high in this regard, 1,600 on an average; milo and wheat are a little lower. Wheat by-products are very much lower. Oats and barley are not as high as wheat and corn. Lard and corn oil supply very high levels of energy. The reasons M.E. values are used are primarily because they are reproducible in different laboratories; they are little affected by nutritional balance; they are highly correlated with performance; they are not markedly influenced by genetic differences; and they are relatively easy to determine compared with productive energy.

There has been a tremendous amount of work on energy in the last decade or so. Just about every university in the country has been working in this field to some extent. Some nutritionists are not satisfied that M.E. values are the best but most nutritionists are. Lavoisier, almost 200 yr ago, was the first one to prove that many of the differences in feeds were related to the energy obtained therefrom. Unfortunately, he lost his head to the guil-

lotine at the time of the French revolution. He performed so many critical experiments with so little equipment, it is a wonder why more cannot be done with all the expensive equipment that is now available.

Energy and protein represent about 90% of the cost of the ration. M.E. values are very valuable because they are a measure of the energy that is available for all purposes including maintenance. Life processes such as maintenance, growth, reproduction, movement, digestion and utilization of food, temperature control, and other diverse activities are dependent upon energy.

The energy content of a food is measured as heat in a specially designed calorimeter and is expressed as calories. This is the amount of heat needed to raise the temperature of 1 gm of water from 14½° to 15½° C; 1,000 cal are equal to 1 kcal.

In the case of energy, protein, and other nutrients, the really important relationship is the ratio of the amount of a nutrient, such as vitamin A, not only to the total amount of feed but also to the energy value of the ration. Relating the dietary concentration of a nutrient to the amount of energy in the diet has much to merit its use in formulating rations.

Since the hen eats primarily to meet her daily energy needs, it is important to have proper amino acid balance. Experiments have shown that the laying hen requires a minimum of 13–14 gm of protein per day. Some claim up to 18 gm is necessary. This is what the bird needs to produce the egg and maintain herself. Her requirements could be met in several ways depending on how you formulate the feed and the feed intake of the bird.

Suppose a flock is laying 75%. To get this amount of protein for an egg a day per bird, the flock has to eat 25 lb of feed per 100 hens. If for some reason such as lack of food intake, the flock consumes only 20 lb of feed for the 100 hens, it does not have enough to supply the eggs so they stop laying. This frequently happens. There is a definite need for daily protein to provide the amount of protein that is in the egg.

It is possible to note a nutritional deficiency just by observing the feathers of the bird. Lack of the amino acid lysine lightens the pigment of turkey feathers so that a year later you can look at the bird and say this bird was deficient in an amino acid at a particular time in its life. Feathers differ from any other type of tissue in that they have specific requirements for sulfur containing amino acids such as arginine and glycine.

It is important to know whether a value is productive energy or metabolizable energy. This whole matter of energy and protein-calorie relationships has been developed within the last few years. The first research of any importance was done in Connecticut. They found that increasing the energy content of the ration by taking out the fibrous ingredients and using high levels of corn, the growth rate of broilers was improved. They attempted to

use fats to further increase the energy values but this did not work out too well commercially. Schweigert recognized that fat deteriorated in the feed. So a fat stabilizer was used in the fat to make high energy feeds. This proved to be an important asset to the broiler industry.

It was just about this time that detergents came on the market and caused a glut in the fat market. Prior to this time, fats were used to produce soap. This matter of high energy rations causes scientists to take a hard look at the bulkiness and texture of the feed. These are all involved in increasing the energy content of the ration. At least part of the beneficial effect of fat in rations can be attributed to increased density of the feed and its effect on palatability. For that reason, pelleting a ration in order to increase its density has somewhat the same value as adding fat. More fat in the feed might be beneficial because it makes the feed a little more dense.

This matter of energy to protein ratio also has a counterpart in its relationship of energy to other nutrients. However, the energy content of the ration had no effect on the calcium and phosphorus requirements for growth and efficiency of feed utilization. When fat is added, the chick requirements for choline, riboflavin, folic acid, and methionine increase. There is a relationship between the chicks' requirement for methionine and for all other amino acids as well. So, it is quite common for nutritionists to calculate not only the protein-calorie ratio but also the methionine-calorie ratio.

The relation of energy to lysine, in general, is similar to that with methionine. In general, higher energy diets produced pronounced sparing action on the water-soluble vitamins. The field is getting even more complicated because there are a number of interactions among several nutrients including the vitamins. Probably, there are multiple interrelationships with respect to energy and trace minerals. The trace mineral specifically studied has been potassium. The chick appears to need more potassium when the energy level is increased. The acceptance and use of calorie-protein ratios to improve balance in formulation has resulted in improved performance of the birds. Optimum ratios worked out have been quite rewarding because they produce a more exact basis for expressing requirements.

COMPOSITION OF FEEDSTUFFS

Corn is higher in energy than all other cereal grains. Yellow corn produces yellow color in the yolks of eggs and in the shanks, beak, and skin of fowls, chiefly due to its xanthophyll content.

Soybean meal which has been thoroughly cooked in processing is the best substitute for protein supplements of animal origin in poultry feeds. Soybean meal is the cheapest source of high quality protein and, along with some animal protein, properly balances the less valuable protein of corn.

Fishmeal is rich in protein of high nutritive value, even more efficient

than the protein of meat scraps as a supplement to the grains. Because of its high cost, fishmeal is generally used in small amounts.

High quality alfalfa meal supplies carotene to help meet the vitamin A requirements and also furnishes B-complex vitamins, calcium, and protein. A primary reason for adding alfalfa meal to the laying ration is to produce the desired yellow color in the egg yolk.

Fats contain 2½ times as many calories of productive energy as does corn. Increasing the energy content of a balanced ration decreases the amount of feed required to produce a dozen eggs and results in a savings in feed cost. Animal and vegetable fats and their mixtures are used in poultry rations.

The laying hen has a calcium requirement of 2.75% of the ration. Ground limestone and oyster shell contain 38% calcium and are the primary sources used to bring the calcium level of the diet up to this level.

Dicalcium phosphate contains 18% phosphorus and 26% calcium and is added to the ration to supply the required phosphorus level. In this way, dicalcium phosphate practically meets the calcium requirement, thus reducing the amount of ground limestone to be added to the ration.

Salt, which is frequently iodized, is added to the ration to meet the sodium requirement of the laying hen.

Methionine is usually the first limiting amino acid in corn-soybean meal rations. It may be added either as DL-methionine or hydroxy analogue calcium.

Vitamin-trace mineral premixes are formulated in such a manner that when added to practical rations they will meet the requirements of vitamins A, D_3, E, riboflavin, niacin, pantothenic acid, choline, and B_{12}, and of the trace minerals, manganese, zinc, iodine, iron, copper, and cobalt.

FEED INGREDIENTS GUIDE

Color and Odor—These are described as what is considered the color and odor of a desirable quality ingredient.

Texture—This is based on US Bureau of Standards Screen numbers. Textures should not be considered as specifications, but are merely guides for particular ingredients available in many areas.

Test Weight—The cubic foot weights are figures which appear to be most generally acceptable.

Microscopic—The microscope and other means of magnification for the examination of feed ingredients are important methods of determining quality. The American Microscopists have published a comprehensive volume on feed microscopy entitled, *Manual of Microscopic Analysis of Feeding Stuffs*, which may be procured through Missouri State Feed Laboratory, Old Post Office Building, Jefferson City, Missouri.

Grain Standards—Official Grain Standards of the United States are published by the US Dept. of Agr.

Sampling and Inspection—Receiving samples: The sample foreman should examine each shipment before unloading, and take samples of the shipment as follows:

Bulk cars—Using a grain sampling probe, take samples from 5 locations in the car—2 from each end and 1 near the doorway.

Bag cars—Using a pointed bag sampling probe, take samples from 20 sacks in the car so as to be representative of the top 2 layers in the shipment.

Tank cars (liquids such as molasses, fats, and oils)—Draw at least 1 qt sample by means of a long-handled dipper, or an approved liquid bomb sample.

Drum shipments (liquids such as molasses, fats and oils, etc.)—Draw samples from at least 10% of the drums in the shipment and make composite samples.

Examination and Inspection—All samples should be examined for the following: (1) dampness; (2) color; (3) odor; (4) texture; (5) caking; (6) foreign material, and (7) infestation.

Alfalfa Meal

Alfalfa meal (17% dehydrated) is ground dehydrated alfalfa. The term "dehydrated" applies only to freshly cut alfalfa which has a moisture content of not less than 50% and which has been artificially dried at a temperature of at least 212°F in a drying process requiring not longer than 40 min. No admixture of sun-cured alfalfa is allowed. The protein content must be at least 17% and the fiber not over 27%.

Color—Medium light to dark green. A brownish green color, as well as presence of numerous brown particles, indicates overheating during the dehydrating process. Although green color and carotene content are roughly parallel, meals of the same color may have very different amounts of carotene.

Odor—Fresh and free from mustiness. It should resemble that of freshly cut grass with a slight caramel odor. A burnt odor indicates overheating during the dehydrating process. Certain weeds when cut and processed with alfalfa impart peculiar scents to the meal. For instance, a soapy odor is usually indicative of wild carrot.

Texture—Fine. 100% must pass a No. 16 screen

Test Weight—Expected—19 lb per cu ft
Range—17 to 22 lb per cu ft
Pellets—36 to 40 lb per cu ft

Pigmentation Sources—The main natural sources of pigmentation, xanthophylls, are the ingredients: dehydrated alfalfa meal, corn gluten meal, and yellow corn. The proportions of effective pigmentation materials as compared with the carotene content in these ingredients are as follows:

Dehydrated alfalfa meal—Xanthophylls 2.5 times the carotene content.
Corn gluten meal—Xanthophylls 8 times the carotene content.
Yellow corn—Xanthophylls 4.5 times the carotene content.

Because they are so closely related chemically to carotene, xanthophylls are destroyed by oxidation almost as rapidly as is carotene during storage. Because of some difficulty of separation of the effective xantho-

TABLE 10.1

CHEMICAL COMPOSITION OF FEED INGREDIENTS

Ingredient	Avg Moisture	Protein	Fat	Fiber	Ash	Ca	P	NaCl
Alfalfa meal, 17%	9 0	17 0	2.0	26.0	10.0	1.40	0.20	...
" " 20%	9 0	20 0	2.5	20 0	10 0	1.60	0.25	...
Barley, grd.	10.0	9.5	2.0	6.5	2.5	0.06	0.35	...
Beans, cull	10 0	21.0	1.5	4.0	6 0	0.10	0 45	...
Blood meal	10.5	80.0	1.0	1.0	4 5	0.30	0.45	...
Bone meal, steamed	9 0	6.0	1.0	0.8	84.0	26 0	13 0	...
Brewers dried grains	11.0	25.0	6 0	15.0	3.5	0.25	0.48	...
" " yeast	6.0	45 0	1 0	2.0	7.0	0 10	1.20	...
Buttermilk, dried	6.0	32.0	5.0	0.0	9.0	1.30	1.00	...
Corn, yellow grd	13 0	8.5	4.0	2.5	1.5	0 02	0.25	...
Corn dist. grd. sols	8.0	26 0	9.0	9.0	5.0	0.20	0 60	...
" " drd. "	8 0	26.0	9 0	4.0	8.0	0.30	1.20	...
Corn gl feed	11.0	22.0	2 0	9.0	7.0	0 40	0.70	...
Corn gl. meal	10 0	42.0	2 0	4.0	2.0	1.10	0 40	...
Cotton seed meal, solv.	10 5	41 0	1.0	13.0	7.0	0.20	1.20	...
Fats and oils	2.0	...	...	...	...	...	...	...
Fishmeal	6 5	60 0	6.0	1 0	20.0	6 0	3.00	...
Fish solubles	50 0	33.0	5.0	0.0	9.0	1.0	0.80	...
Hominy	10 0	10.5	5.5	5.0	2.5	0.25	0.50	...
Kafir & milo	12 0	9.0	3 0	2.5	1.5	0.03	0.30	...
Meat & bone scraps	7.0	50 0	8 0	2.5	28.5	10.0	5.0	...
Molasses, cane	25.0	3.5	0 0	0 0	10.0	0 60	0.10	...
" corn sugar	20.0	0 5	0.0	0.0	3.0	0 50	0 05	...
Oat meal	10 0	15 0	5 5	3.0	2.0	0.05	0 40	...
Oats, grd.	11.0	10 0	5 0	12 0	3.5	0 10	0.40	...
Phosphorus supplements								
(Dical phos.)	...	..	..	...	...	24 0	18.5	...
(Defluor. phos.)	...	..	...	...	...	34 0	14.0	...
(Curacoa phos.)	...	..	...	...	...	35.0	15 0	...
Poult. by-prod. meal	5 0	55 0	12.5	2.5	12 0	3.5	1.7	...
Skimmed milk, dried	6 0	33 0	0.5	0 0	8.0	1.3	1.0	...
Soybean meal, solv	11.5	45.0	0.5	6.5	6.0	0.25	0 60	...
" "	11.0	50.0	0.5	3.0	5.5	0.20	0 60	...
Wheat bran	12.5	15.0	4 0	10.5	6.0	0.10	1.20	...
Wheat, grd.	11 0	14 0	2 0	3 0	1.8	0 05	0.40	...
Wheat feed flour	13 0	14.5	2.5	1.5	1.0	0.05	0.50	...
Wheat middlings	12.0	16 0	4.0	8 0	4.5	0 10	0 90	...
Whey, dried	5.5	12.0	0.2	0.0	10.0	0.75	0.80	3 0

phylls (lutein and zeaxanthin) chromatographically, the assay of feeds and feed ingredients for these xanthophylls is not considered as accurate as the determination of carotene by chromatography.

Barley (Ground)

Ground barley is the entire product obtained by grinding barley. It shall consist of not less than 80% sound barley and shall not contain more than 3% heat-damaged kernels, 6% foreign material, 20% other grains or 10% wild oats.

Color—Light to tannish-gray.

Odor—Fresh and sweet with no mustiness.

Texture—Fine. 90–95% passes a No. 16 screen. Screens on hammer mills used for barley are usually 6/64 in.

Test weight: expected 25 lb per cu ft; range—24 to 26 lb per cu ft.

(Whole barley is purchased as good feeding grade barley—test weight 40 lb per bu)

Beans (Cull)

Cull beans consist of split, small, or damaged beans of the following varieties: field or navy, lima, kidney, pinto, tepary. All have the same general composition and feeding value.

Color: Creamy to off-white.

Odor: No mustiness or moldy odor is acceptable.

Texture: Cull beans should be ground through a 10/64 in. hammer mill screen. Approximately 95% passes a No. 16 screen.

The chemical composition of common feed ingredients is given in Table 10.1.

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Cereal is the basic item in many human and animal diets. Americans have been called "corn-fed" people. Indian corn (maize) is our basic cereal and it is used for feeding chickens and cattle to provide meat and dairy products. Corn flour is used to make tasty breads and cakes. Corn oil is a basic cooking ingredient with dozens of uses. This domesticated member of the grass family is a native to the New World that thrives in our climate, but does not thrive in many densely populated regions of the world. People of warm, humid regions depend on rice as their basic cereal. Millet does well in a drier climate with either a warm or hot summer season and thrives in parts of India, China, Africa, and Russia. Millet is the diet of one-third of the world's human population. Millet flour is rich in nutrients but it does not work with yeast to make spongy doughs. Millet bread, though nourishing, is flat and heavy.

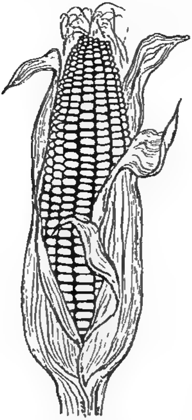
The basic cereals of the human diet are descendants of ancestors of wheat and belong to the grass family of plants. Farmers improve their crops through selection, but recently, geneticists have improved on selection.

Corn is the most important cereal grain for poultry in the United States, and is used more in rations than any other grain (mostly for energy). It is low in fiber but its protein quality is rather low. It is also poor in calcium and vitamin E but high in carotene, or provitamin A. By-products of corn milling, corn gluten feed and corn gluten meal, are commonly used. Corn gluten feed contains corn gluten meal, corn bran, and sometimes corn solubles with enough gluten to guarantee 25% protein. The meal comes from the same milling operation in which starch is obtained to make syrup in the wet milling process. Meal contains 40 or 60% protein, is a good source of pigmentation and quite low in riboflavin.

Second only to corn in importance is wheat which is grown mainly for human consumption. Birds like wheat and may overeat if not restricted. The protein content of wheat varies widely depending on the location where it is grown and type of wheat. In the United States most wheat comes from the Plains states and is spring wheat which contains 16% protein. Soft wheat used for pastry is higher in protein. Wheat is higher in energy than bran and should not be higher than 9% fiber.

Pound for pound substitution of wheat for corn is made where wheat is available economically. Since wheat does not have xanthophyll, some pigmentation is needed. If wheat is ground too fine, pasting of the mouths of the birds will occur; this is objectionable.

Bran, another product of wheat milling, is the coarse outer covering of the kernel. Bran is low in energy, has a mild laxative quality, and is a good source of the B-vitamins. It is also high in phosphorus, much of which is in the form of phytin. Birds do not utilize phytin, an organic phosphorus



Courtesy of Corn Products Co., New York, N.Y.

FIG. 10.3. CORN IS THE MOST IMPORTANT GRAIN FOR POULTRY FEEDING IN THE UNITED STATES

compound, well because they lack the proper enzyme to break it down. Wheat middlings are obtained from flour milling and contain some hulls and flour.

Soybean meal is the most commonly used plant protein feedstuff. Soybeans have to be cooked properly to be of value because in the raw state they contain growth inhibitors that affect utilization of the protein.

Oats are used in rations and have the same general amino acid deficiencies as other grains. The standard weight of oats is 32 lb per bu, but on the market may be lower in density. Oats contain 12% protein. They are low in energy and consequently are not used much in poultry feed, except when the price is favorable. Because of the hulls, oats tend to prevent feather picking and cannibalism.

Grain sorghums do well in the Southwest where there is less rainfall. Milo and kafir do better there than corn and in poultry rations are equal to corn as far as energy is concerned but the protein is of poor quality. They have no vitamin A or pigmentation value.

Barley is used liberally in the West, but in the East it is usually a cash crop purchased by the fermentation industry. Barley is not as good as corn but is used in some regions where corn will not grow satisfactorily. It has no

TABLE 10.2

PRODUCTION OF MAJOR AGRICULTURAL COMMODITIES IN 1965

(In Million Metric Tons)

	Wheat	Barley	Oats	Corn	Rye	Sorghums Millet	Soy-beans	Rice	Pulses	Ground-nuts	Cotton-seed	Copra	Sunflower Seed
Western Europe	48.8	31.0	11.9	14.9	5.4	...	.	. .	...	...	...	...	...
Eastern Europe	18.6	6.9	4.2	11.3	11.5	...	.	...	...	...	...	...	...
U.S.S.R.	59.7	20.3	6.2	8.0	16.2	2.2	..	.	...	...	...	...	5.4
North America	53.5	13.2	19.9	105.3	...	17.1	23.2	2.3	...	...	5.6	...	...
Latin America	10.2	...	...	31.2	...	...	..	7.1	...	1.4	3.5	0.24	0.8
Far East	19.0	...	...	13.1	...	15.2	1.1	92.1	10.3	5.3	...	2.7	...
Near East	18.4	6.8	...	3.9	...	...	...	2.3	1.2	...	2.6	...	...
Africa	4.4	2.7	...	13.2	...	11.5	...	2.3	1.6	4.8	...	...	...
World	239.9	88.4	44.9	200.9	33.1	46.0	25.5	107.4	13.1	13.0	19.3	3.3	6.2

vitamin A activity and is less palatable than corn. Frequently, birds have to be trained to eat it.

Some other grains are rye, rice, and rice bran. There is considerable rice production primarily in the lower Mississippi River states. Rye is used in the East to a limited extent but is not too good a grain for poultry because droppings become very sticky and adhere to the feet of the birds.

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Corn

The United States produced over 50% of the world's crop with its 4.7 billion bushels in 1968. No other crop equals corn in this respect. In the late 1930's, the yield barrier was broken with the introduction of hybrids.

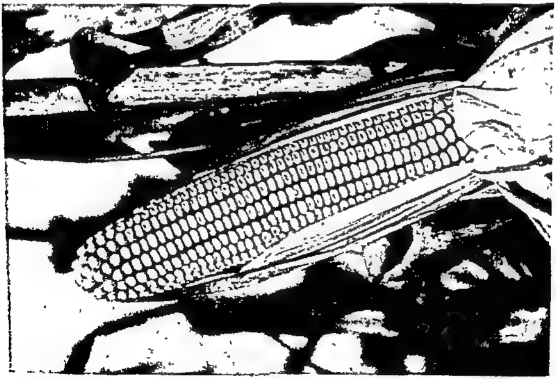

FIG. 10.4. DENT CORN IS A BIG-EARED, LARGE-KERNELED CORN EASILY IDENTIFIED BY THE DENT IN THE BROAD END OF THE KERNEL

It occurs in hybrid and open-pollinated varieties and most is yellow in color. It is the basis of poultry meat and eggs on the U.S. dining table.

Theoretical yields of 400 bu or more per acre have been predicted, and actual yields of over 300 bu have been achieved. Corn leaves are very efficient in utilizing solar energy in photosynthesis. More total digestible nutrients are produced from corn than any other crop. Productivity has been increased by improvements and changes in culture, such as earlier planting, higher plant populations of uniform stand, equidistant precision planting, adequate starter fertilizer, minimum tillage, irrigation, application of fertilizer during the growth of the crop through irrigation water or otherwise, and use of herbicides that result in a weed-free environment.

A major limitation to the attainment of higher yields in corn is the length of time required from planting until the leaf canopy covers the ground area. Corn plants of the future will likely be single-cross, short-stalked prolific hybrids, having a high grain to stalk ratio and resistance to lodging. Uppermost leaves will have a vertical orientation, lower leaves more horizontal. Tassels will be small and plants cone-shaped. There will be equidistant planting and high plant populations, capable of capturing a maximum of solar energy for photosynthesis.

High-lysine corn looks promising. There is a good possibility of developing high-lysine hybrids that yield as well as normal corn varieties. Yields of high-lysine hybrids average 85% and one was as high as 95% of yield of the normal hybrids. Plant geneticists have known since the 1930's that the opaque-2 gene existed, but it was in 1964 that researchers discovered that this gene is responsible for the high-lysine content in corn kernels. Opaque-2 kernels are soft and floury and contain slightly more moisture at harvest and weigh less than normal dent kernels.

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Wheat

Wheat is the most important food crop of the world but of less value as a feed for poultry. It is grown over a wider area and produces more tonnage than any other commodity. Superior new varieties, yielding 100 and more bushels per acre are available. The Gaines and Nugaines are the most successful varieties ever developed for the Pacific Northwest and for irrigated areas of the entire western region; they are true semidwarf wheat varieties.

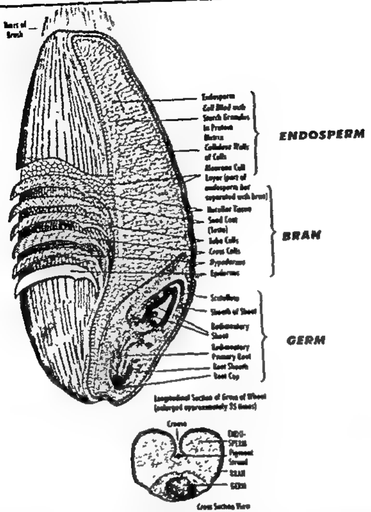
Wheat varieties of the future will be high yielding, short straw, rust-tolerant, and resistant to lodging, smuts, mildews, root rots, virus diseases, Hessian fly, cereal leaf beetle, saw fly, and winter injury. Also, they will be responsive to higher rates of fertilizer and water. Hybrid wheat of the spring type and hybrid winter wheat will be introduced soon.

Wheat is the most universally grown cereal in the United States and in many parts of the world. Its composition varies with the variety, soil, and cultural treatment received. Milling wheat produces flour for human use and appreciable quantities of by-products for animal feeds. Wheat is primarily a source of carbohydrates or starch. By-products of wheat include: (1) bran, consisting almost entirely of the outer coatings of the wheat kernel; (2) shorts or brown shorts; (3) standard middlings, or middlings consisting of the fine particles of bran and germ with very little Red Dog; (4) Red Dog sometimes called "light shorts," a product from the tail of the mill consists chiefly of the aleuron layer with small particles of bran, germ, and flour; (5) germ, consisting of the wheat germ separated in the milling process by grinding; and (6) flour which normally goes into human foods.

Hard, red winter wheats are grown in Oklahoma and Kansas, and hard, red spring wheat comes from Montana and North Dakota. White wheat is obtained from Washington and soft, red winter wheat from Indiana. Seventy-two to seventy-five percent of the wheat is recovered as flour, 12 to 15% as bran, 7 to 8% as shorts, 1½ to 4½% red dog, and 1% germ. Flour is lower in protein than the other by-products and germ has the highest percentage of protein and the lowest yield. Shorts are the next highest in protein and are higher in protein than bran and the yield is second to bran. Protein content of wheat varies widely, influenced by environmental conditions, fertility, and variety of wheat.

The metabolizable energy of different grains are of considerable significance in poultry feeding; wheat is lower than corn. Because of the large portion of grain contained in poultry feeds, the amino acids present in the protein are of importance. Most of the essential amino acids in wheat are readily available.

In some Washington tests, various strains were fed to turkeys along with a protein concentrate or balancer. Wheat was consumed in greatest



ENDOSPERM about 83% of the kernel. Source of white flour. Of the nutrients in the whole kernel the endosperm contains about: (1)

70-75% of the protein
43% of the pantothenic acid
32% of the riboflavin
12% of the niacin
6% of the pyridoxine
3% of the thiamine

B-complex vitamins.

Enriched flour products contain added quantities of riboflavin, niacin and thiamine plus iron, in amounts equal to or exceeding whole wheat—according to a formula established on the basis of popular need of these nutrients.

BRAN about 14 1/2% of the kernel. Included in whole wheat flour but more often removed and used in animal or poultry feed. Of the nutrients in whole wheat, the bran, in addition to indigestible cellulose material contains about: (1)

86% of the niacin — 42% of the riboflavin
73% of the pyridoxine — 33% of the thiamine
50% of the pantothenic acid — 19% of the protein

In animal and poultry feeds, these nutrients are available. In human diet, the cellulose material of the bran tends to speed the passage of food through the digestive tract—making the total nutritive contribution less than from enriched white flour products.

GERM about 2 1/2% of the kernel (1). The embryo or sprouting section of the seed, usually separated because it contains fat which limits the keeping quality of flours. Available separately as human food, but usually added to animal or poultry feed. Of the nutrients in whole wheat, the germ contains about: (1)

64% of the thiamine
26% of the riboflavin
21% of the pyridoxine
8% of the protein
7% of the pantothenic acid
2% of the niacin

The kernel of wheat is a storehouse of nutrients needed and used by man since the dawn of civilization. Today's bread, flour and cereals—enriched, whole grain and restored—are one of four groups of food recommended for optimum nutrition by the U.S. Department of Agriculture. This popular, low-cost group includes such foods made from wheat as bread, rolls, biscuits, muffins, pancakes, breakfast cereals, macaroni, spaghetti and noodles. Nutrients listed below are considered essential in human diet.

As a product group in the U.S. Department of Agriculture's recommended Daily Food Guide for good nutrition—bread, flour and cereals make a generous contribution to human requirements for the B-vitamins thiamine, niacin and riboflavin and the mineral, iron. They also help fill daily needs for *protein and calcium. The other three food groups are:* milk and milk products; meats, poultry, fish eggs and dry lentils; fruits and vegetables. Nutritionists advise eating a variety of foods from each of the four groups every day to obtain all the nutrients necessary for adequate diet. With fresh, frozen, canned and prepared foods readily available, it is easy for everyone satisfy nutritional requirements by following the Daily *Food Guide.*

Research Association of British Flour Millers, Cereals Research Station, St Albans, England, 1960

FIG 10 5 A KERNEL OF WHEAT

amounts, followed by corn, oats, and barley. For many years, wheat has been used extensively in the Pacific Northwest, in fact, wheat constitutes essentially the only cereal grain used in feeding laying hens. Egg size, shell thickness, and egg quality, as indicated by Haugh units, are essentially the same for all grains. Corn and wheat give identical values in pounds of eggs per pound of feed consumed and just about the same effect on egg size. Oats, barley, and milo give slower rate of increase in size than corn.

Wheat is a highly acceptable grain for use in poultry production although a slightly lower growth and feed efficiency are obtained in some instances when wheat is substituted for corn. Some varieties of wheat are improved in nutritional value by addition of either an enzyme supplement to the diet or water treatment of the wheat. Flake milling by-products are effectively utilized in poultry production and wheat makes an excellent replacement for either corn or milo in poultry feeds. The number of calories of metabolizable energy per pound is essentially the same for corn and wheat, but milo contains 5% less metabolizable energy than corn. The average percentage of protein in corn is 9, in milo 8. One pound of wheat can replace 1.25 lb of milo or 1.1 lb of corn.

A number of factors beside energy and protein contents must be considered when wheat is used to replace corn or milo. These factors include amino acid balance, stickiness of ground wheat due to the gluten content, desirable color of egg yolks, and the color of fat on broilers and market turkeys.

Protein in wheat is lower in the amino acids leucine and alanine, and somewhat lower in threonine. Levels of glutamic acid and choline in wheat exceed those in corn and milo. Wheat contains gluten which makes the ground wheat sticky when it becomes wet and gives the feed a tendency to adhere to mandibles of chickens and turkeys. To overcome this tendency, pulverized oats, ground barley, or wheat bran are used to make the texture of the mash coarse. Wheat is devoid of the xanthophyll pigments, but this can be overcome by the use of alfalfa meal or corn gluten meal or their combination.

It has been reported that wheat germ has a deleterious effect on the growth of chickens and that this is asssociated with an increase in fat content of droppings. It is claimed that these results are caused by a thermolabile toxin in the raw wheat germ which is destroyed by heating. Close observation during experiments where raw wheat germ was part of the diet indicated that during and after feeding, the food forms a paste on the beaks in combination with salivary mucous and water and that these birds ate correspondingly less and grew less well. The birds clean their beaks on the wire of the floor, thus adding sufficient food fat to the droppings to account for the differences in fecal fat between the control and wheat germ

groups. This simple explanation for the effects of raw wheat germ questions the idea of a thermolabile toxin.

Feeding "new" wheat to poultry is dangerous and results in serious mortality in flocks. It may involve feed dealers in lawsuits brought about by poultrymen to recover losses. The higher the moisture content of the new wheat, the more dangerous it is to feed. Wheat which has been kept in a bin or elevator and undergone a "sweat" is safe to feed. New wheat causes the digestive system to become full and a decided enteritis and diarrhea are noticeable. Some believe that mortality is a direct result of toxins produced by fermentation of the new grain in the digestive tract. No specific organisms have been isolated but symptoms of digestive troubles such as profuse diarrhea and darkened comb are observed.

Other grains such as oats in the milk stage if consumed before they are mature cause trouble similar to the feeding of new wheat. Currently, wheat varieties are self-pollinated, comparable to an inbred line of crops such as corn. Several problems related to the production of hybrid wheat are not solved up to the present time. Lack of complete fertility restoration in the hybrid plants is the most troublesome problem which results in poor set and hence reduces yield. Another problem is the low percent set on the male sterile parent of the hybrid when planted in alternate strips with a fertility restoring parent. This condition reduces the amount of hybrid seeds. One of the biggest uncertainties concerning hybrid wheat is that of economics. Can hybrid wheat be raised and sold at prices profitable to both the producer and farmer? Yield increases of 25 to 35% occur as an advantage for hybrid wheat. Other advantages are its ability to stand unfavorable environmental conditions such as low temperature, soil heaving, and drouth. Hybrids are more vigorous in growth habit and better buffered genetically to withstand conditions than inbred varieties. Hybrid seeds probably will not be available for farm planting for some time.

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Oats

Oats are probably the best single grain for young growing chicks and turkeys, as well as being excellent for laying hens. Up to 40% of the ration may be oats when the quality is good and the price justifies it. Chicks fed a high oats diet grow faster and more rapidly than on other common grains. Oats also reduce cannibalism and feather picking in growing and laying flocks. Chicks from hens on high oat rations are more vigorous than those on high corn diets. High oat diets produce chicks with light or no yellow pigment in the beaks and shanks. Oats as light as 17 lb to the bushel may be ground and used in mashes for growing chicks, laying hens, and mature turkeys when the amount is limited to 28% or less. For fattening, oats are far less efficient than corn. Where oats are the main cereal in the chick ration, there are less slipped tendons due to the higher manganese content of oats than is the case with corn. The factor(s) which speeds growth and feathering is in the hulls.

For egg production, corn is far better as a single grain than oats or wheat, but mortality is lower with hens on a high oats diet. Fertility of eggs is approximately equal from oats or a mixed grain ration. Oats do not have carotenes as in the case of corn and, therefore, vitamin A must be made up in the mash to balance this aspect of corn. The mixed grain type of ration is preferred to a ration made up of any single grain because certain deficiencies in each grain are compensated for by another grain. The use of oats in poultry feeds depends on the availability of good quality oats at a price that justifies such usage. While grains are ranked in the order of oats, barley, wheat, and corn for growth, the reverse order is apparent for fattening. One of the most noticeable things about corn-fed turkeys is their poor feathering and the fact that it takes six weeks longer to reach marketing weight than when fed wheat. The free-choice feeding of whole oats has been used to advantage for chicks and pullets grown in confinement. Whole oats are kept before the chicks after five weeks of age, and comparatively little trouble is experienced with feather picking or cannibalism. Oats are fed in a variety of ways. Individual poultrymen have their preferences which determine their choice of procedures.

The feeding of germinated oats was formerly practiced and is worthy of consideration if the caretakers' time will permit the extra time and labor involved. High quality heavy oats (not less than 32 lb per bu) are necessary for free choice feeding. Cooked oats are preferable but not essential if a good grade of heavy uncooked oats is available. The use of oats generally means a corresponding reduction of corn in the ration and in some instances this may result in a deficiency of vitamin A. As stated, oats have the highest protein content and the best balanced protein of any cereal grain now being

produced. Several wild oats have protein contents as high as 30% compared with 18 to 19% protein for the best commercial varieties. Some of the wild oats species produce very large kernels and attempts are being made to introduce these traits into present varieties by breeding. Wild oats cannot be grown itself as a crop because the seed shatters before it matures, making it impossible to harvest.

In the future, oats could become one of the most valuable crops. If one of the new oat varieties yielded 150 bu per acre and contained 25% protein, the total quantity of protein per acre would exceed that of any crop now being produced. Oat yields in the United States average 50 bu per acre, but yields of 100 to 130 bu are not uncommon in major oat-producing states.

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Barley

Barley, one of the world's oldest cultivated grains, is most resistant to cross breeding. However, a hybrid has been produced, Hembar, which yields 15 to 35% more grain.

In the Pacific Northwest, California and many European countries, barley is the principal grain grown for feeds. It is an excellent feed for all classes of poultry and growing turkeys. Higher in protein than corn, the quality is somewhat better than that of corn. Barley is less palatable, higher in fiber, and lower in energy than corn. Consequently, 1 lb of barley is not equal in feeding value to 1 lb of corn.

Barley is ground or rolled to obtain maximum feeding value. Barley is higher in niacin than corn, thus a niacin deficiency never occurs when barley is fed as the principal part of the ration. Value varies with its test weight per bushel because high weight barley contains less fiber and more starch. It contains only traces of vitamin A, whereas yellow corn is a fair source. Whole barley is worth from 81 to 85% as much as whole corn. Barley is sometimes infected with scab.

About 80 to 85% of the total feed consumed by turkeys is eaten between 10 to 24 weeks of age and the greater portion of this is grain in some form. Whole and pelleted barley can be fed and turkeys produced of approximately the same weight and requiring the same amount of feed to produce a pound of gain as turkeys fed corn. The feeding value of barley can be

greatly improved for young chicks or turkeys by either water treating the grain or adding to the diet a crude enzyme supplement produced by fermentation. The magnitude of response is much greater for barley than for wheat.

Some varieties of barley produced in different areas of the United States respond to either enzyme supplements or water treatment or both and others were unimproved. There is a correlation between areas of production in the United States and the type of response obtained. Washington researchers found in 1957 that the feeding value of barley grown in the western states could be improved by adding certain enzyme supplements. Most of this work was involved with egg production. Chicks fed hull-less barley performed about the same as those fed regular barley, both types being inferior to corn, milo or wheat. When enzymes were added to a hull-less barley diet, growth rate and feed efficiency were increased and the droppings became less sticky. A protease enzyme may be one of the essential substances, but evidently others are needed for maximum results. Apparently chicks depend on enzymes that are either in or on the barley to help them digest the grains. The amounts naturally present in hull-less barley are not sufficient to allow the chicks to digest this grain as completely as can be done when more are added. When the grain is soaked at room temperature, these enzymes and probably others produced by microorganisms during the soaking period partially digest the grains; little further improvement is noted when more enzymes are added to the ration. When the barley is soaked at a high temperature, enzymes naturally present are inactivated and enzyme production by microorganisms during the soaking and drying period is minimized.

Other Small Grains—The attributes of new high-yielding, short-straw types of wheat and rice apply also to barley, oats, and rye. High yielding barley varieties have more upright leaves which permit greater light penetration.

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Grain Sorghum

Exceptionally high yields (675 bu per acre) have been obtained experimentally. Hybrid selections are much improved, and meet the stress of high plant populations, heat, and drought. Changing cultural practices, and plant types may be equally as important for this crop as for corn.

The seed color of grain sorghum varieties is not related to feeding value. The amount and availability of various amino acids vary considerably among varieties of milo. Feeding value is closely related to amino acid availability. Neither feeding value nor amino acid availability is related to feed color. Most of the milo varieties available commercially are high in feeding value.

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Rye

Rye grain successfully replaces up to 400 lb of wheat shorts or corn in a 2,000-lb mix. Advantages claimed are lower feed cost due to lower cost of rye grain, 5% less feed consumed, 3% increase in egg production, and drier droppings. Rye has a higher content of methionine and cystine compared to wheat shorts or corn.

The use of rye in poultry diets is not new. Rye was tested as a feed ingredient at the University of Wisconsin in the early 1930's. It was unsatisfactory for starting chicks but used as part of the mash for growing pullets and laying hens. Experimental rations containing up to 45% rye gave satisfactory results with laying hens. The use of rye grains is recommended only when home-grown rye is available or when rye is cheaper than other grains. Rye infected with ergot fungus should be avoided at any level.

Rice

Rice is second to wheat as a world food commodity. A billion people depend on it as their major source of energy. Less rice than wheat is used for feed for poultry. At the International Rice Research Institute in the Philippines, selections have been made from crosses between the tall tropical indicas and the short-statured types from Taiwan. The yield potential of the new short-strawed type is severalfold that of established types because of their resistance to lodging and response to nitrogen fertilizer. New records in the productivity of rice are being achieved.

Yields in wheat and rice are made up of three components: number of heads, kernel number, and kernel weight. The new short straw types re-

spond to adequate moisture, nutrient reserves in the soil, and environment at the time when the growing point of the stem initiates the head or panicle and determines the potential kernel number. Optimum yield, thereafter, is a result of limited lodging achieved by a short stiff straw. Yield capacity is conditioned by these variables.

The shape and form of plants have been altered genetically so they respond to fertilizer without lodging. Most old types of rice take 6 to 7 months to mature. New short-straw, high-yielding varieties mature in 4 to 4.5 months.

Millet

The feeding value of red and white proso millet is 95 to 100% that of corn in the starting, growing, and laying rations of chickens. It is fed in starting rations to equal 44% of the all-mash ration. The supplementary values of grains when fed with red proso ranked in the order of oats, barley, and corn when based on their rate of growth. The best growth or feed utilization occurs with equal amounts of proso millet and either oats, barley, corn or wheat. Ground proso millet is found in growing rations to equal 52% of the mash ration, and up to 100% of the scratch grain ration. Millet is fed in laying rations equal to 43% of the mash ration and 100% of the scratch grain ration. Because of its small size it is added to the laying mash unground, although when this is done 9% more feed is required to produce a dozen eggs. Neither egg production or hatchability is improved by increasing either the amount of alfalfa leaf meal or meat and bone scraps.

Proso millet is a late-sown catch crop. It is grown on the Northern Great Plains and other sections with a similar climate. Proso is distinguished from foxtail and barnyard millet chiefly by the head or inflorescence (the seed bearing part). It is known by names such as hog millet, broom corn millet, or "hershey." Proso millet is classified red or white depending on the color of the hulls. The bran or seed coat is the same color in all varieties. The average yield of proso in pounds of grain per acre is less than that of either wheat, oats or barley, although in rather dry seasons, proso often outyields green feeds.

Millet crops, on a small scale, are grown in several regions for bird seed and hay for cattle. The average millet plant is a tall, straight tuft of leafy spikes arranged around several stalks that are crowded with clusters of tiny seeds. The crop is ready for harvesting after three months. Varieties are named after their bushy stalks of seeds—broom corn, foxtail, finger, and cattail. The common barnyard millet resembles its wild ancestor and might be taken for a field of grasses. The cattail millet can be grown in poor sandy soils where the climate is too hot and dry for any other cereal. Fields of millet are grown in certain parts of Kansas, Texas, Missouri,

and the Dakotas to provide all the birdseed for our feathered pets plus some hay for cattle.

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MOLASSES

Molasses as feed has expanded in use sharply in recent years. It competes with corn and is more advantageous at one time than another. Where there have been surpluses, prices have been very low for long periods. Molasses is moved from off shore areas in large quantity in ocean tankers and in the United States in tank cars to feed mixers. Inedible molasses comprises cane blackstrap, beet molasses, hydrol (corn molasses), citrus molasses, and wood molasses and is a by-product of raw sugar production, cane sugar refining, beet sugar and dextrose production, citrus canning, and concentrate processing. Over 400 million gallons are used annually, mostly from Caribbean and European countries; mainland United States produces only a 1/6 of the total. Molasses was used in World War II for the production of alcohol to manufacture rubber; petroleum products have taken this market releasing molasses for use in animal feeds.

Molasses is substituted for carbohydrate ingredients in poultry feeds. Feeding value is 70% pound for pound for corn. Molasses makes feed mixtures palatable, particularly feedstuffs such as screenings. Molasses is also dried into molasses products; they contain from 40 to 75% molasses in combination with absorptive carriers, such as corn oil meal and bagasse pith. These products are handled in 50- and 100-lb bags as compared to 600-lb drums for liquid molasses. This permits the availability of small quantities of molasses to small users and eliminates the trouble and expense of heating and diluting liquid molasses; it also permits ease in mixing with other feed materials. Dried molasses costs substantially more than liquid molasses on a molasses basis.

Types of Molasses

Industrial molasses are those used for purposes other than direct human consumption and include the following. (1) Cane blackstrap molasses is a by-product of the manufacture of sugar from sugar cane and usually contains slightly less than 55% total solids. (2) Refiners blackstrap is a by-product of the manufacture of white sugar from raw cane sugar. The latter

molasses has approximately the same total sugars and chemical analysis as cane blackstrap molasses. Raw cane sugar and blackstrap molasses are manufactured in mills located in areas where sugar cane is grown. Refiners are separated geographically from raw mills and thus blackstrap molasses production in the raw cane sugar stage and refiners blackstrap production in the refined sugar stage are separate products. (3) High-test (or invert) molasses is a product made from sugar cane without the usual granulation and extraction of sugar and contains from 72 to 75% total sugars, less than 2% protein, and 82 to 86% total solids. (4) Beet molasses is a by-product from the manufacture of beet sugar and contains from 48 to 53% total sugars, 6 to 10% protein, and 80 to 85% total solids. (5) Hydrol is a by-product of the manufacture of refined corn sugar (dextrose) and contains 62 to 64% total sugars and less than 1% protein and about 75% total solids. (6) Citrus molasses is a by-product of citrus canning made by concentrating waste waters and contains 41 to 43% total sugars, slightly less than 14% protein, and 70 to 73% total solids.

A newer product, "Wood molasses," technically hemicellulose extract, is said to be nutritionally equivalent to cane or blackstrap molasses. It is a by-product of the production of hard board and is the concentrated, soluble product that comes from the steam treatment of wood at elevated temperatures and pressures without the use of acids, alkalizers or salts. It contains both pentose and hexose sugars and their precursors and a total carbohydrate content of not less than 55%. Its "Brix" (concentration and percent of sugar) is not less than 65%. Most of this molasses has been used in feeding beef cattle so far.

Louisiana and Florida supply all of the U.S. cane blackstrap. Refiners blackstrap is produced in Louisiana, Texas, Georgia, Maryland, Pennsylvania, New York, Massachusetts, and California. Citrus molasses is produced primarily in Florida; hydrol principally in Iowa, Illinois, Indiana, and Texas. Puerto Rico and Hawaii are also important suppliers of molasses for U.S. use. Cane blackstrap is preferred by feed mixers because of less mechanical difficulties in the mixing process.

Feeders become accustomed to the sweet odor and the moist feel of feeds containing cane blackstrap. Some object to the taste of beet molasses and its laxative effect as compared to cane blackstrap. Hydrol does not have the sweet odor of cane molasses nor does it give feed a moist feeling. Because of its quality of more rapid penetration of feed materials, hydrol is sometimes blended with blackstrap to assist in marketing. The dextrose in hydrol crystallizes in transit and storage, and formerly clogged mixing equipment. Crystallization is now prevented by the addition of alkali to arrest dextrose crystallization.

In the manufacture of beet sugar, the solution of sugar extracted from

the sliced raw beets is evaporated until a syrup is formed and the maximum amount of sugar has been crystallized. These crystals are then separated from the mother liquor by centrifuging. The condensed dark-colored liquid is molasses, containing 60% digestible nutrients of which 3½% is protein and the remainder carbohydrates. It contains 5% of alkaline salts which have a laxative effect in poultry. Beet molasses has fully as high feeding value as cane molasses. It is also derived from Steffen's filtrate or waste waters where it is concentrated to approximately 60% solids. Glutamic acid and betaine may be isolated from Steffen's filtrate.

Hydrol came into use during World War II when there was a shortage of blackstrap. Experiments have proved that there is little choice between hydrol and blackstrap, as far as nutrition is concerned. Citrus molasses differs in odor and taste from cane blackstrap and there is more difficulty in mixing it. The citrus industry processes it primarily as a waste disposal measure. In this process orange and grapefruit peels and pulp are run through a hammer mill. Water and juice are extracted from the material and the liquid is condensed in multiple-effect evaporators.

Blending Equipment

Molasses blending equipment is common in many feed mixing plants in order to take advantage of the savings in molasses. Delivered by tank truck or car it is used as a substitute for more expensive carbohydrate material. Storage capacity is needed to handle twice the size of the anticipated unit of purchase because of the difficulty in scheduling delivery. Some feed manufacturers produce highly concentrated protein and mineral supplements with molasses for small mixers and farmers.

Molasses is a popular ingredient in feed mixes to improve palatability and it frequently is one of the cheapest sources of carbohydrates. There are some difficulties in mixing molasses in poultry feeds because it tends to ball into small masses. Individual birds may consume these masses in quantities large enough to disturb their digestive processes.

Although molasses is most valuable for its high content of readily available energy, it is also a source of highly available trace minerals and important vitamins such as vitamin E. The molasses content usually is 2½% or less in poultry rations to bind materials and provide a mild laxative effect. Not more than 5 to 7% of molasses is added to all-mash chick rations, or there will be a slight decrease in growth, an increase in feed intake, and slight lowering of feed efficiency. Levels from 2½ to 5% slightly lower feed efficiency. Levels from 2½ to 5% are used in turkey starter feeds and broiler rations without affecting significantly the average weights of the birds. Cane blackstrap decreases dustiness, improves appearance and odor, and assists in pelleting operations.

In Hawaii, high concentrations of B-grade molasses are fed to chickens as a substitute for yellow corn in starting rations. This molasses is a valuable carbohydrate feedstuff for poultry, particularly when the importation of cereal grains is curtailed either by shipping strikes or governmental edicts.

TABLE 10.3

COMPOSITION OF FEEDSTUFFS FROM AROUND THE WORLD

Country	Feedstuffs	Prot.	Fat	Fiber	Calcium	Phos.
		%	%	%	%	%
Congo	Peanut meal	45.0	8.4	3.9	...	...
Congo	Palm nut meal	16.2	5.8	14.8	...	...
Sudan	Sesame meal	41.6	14.66	7.25	...	...
Sudan	Peanut meal	21.8	8.2	27.05	...	...
Tanzania	Pyrethrum Marck meal	6.5	1.7	19.2	...	...
Tanzania	Cassava meal	1.3	0.5	2.1	...	...
Tanzania	Lucerne meal	18.5	2.5	18.6	...	...
Tanzania	Barley meal	10.0	1.0	5.2	...	...
Tanzania	Sunflower meal	19.2	10.4	38.0	...	...
Tanzania	Sim-Sim meal	37.8	19.3	7.3	...	...
Dominican Republic	Palm nut meal	7.2	6.0	29.2	...	...
Guyana	Shrimp meal	37.5	1.5	7.5	...	...
Guatemala	Yucca meal	13.6	0.08	9.34	0.35	0.31
Guatemala	Corozo nut meal	15.8	8.45	14.78	...	...
Panama	Corutu (ear tree pod meal)	14.0	4.3	10.8	0.14	...
Burma	Prawn meal	41.7	2.02	11.31	8.27	1.87
Thailand	Extracted fish meal	41.3	...	2.2	6.37	3.22
Iran	Kashk (dried yogurt meal)	70	...	...	...	...
Iraq	Broad bean meal	21.6	0.97	8.3	...	...
Iraq	Ground date pits	6.2	5.92	17.82	0.18	0.61
Iraq	Safflower seed meal	23.0	27.9	6.57	...	...
Iraq	Green gram seed meal	24.7	1.01	5.26	...	...
Bolivia	Chemopodium quinoa meal	11.8	6.1	2.4	...	...
Uruguay	Hoof and horn meal	88.0	1.1	0.43	0.45	0.80

Source: J. T. Gibbons, Inc., New Orleans, La

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PART 3 Hormones

Hormones are chemicals in one part of a living organism which are carried by the body fluids to another part where they produce physiological responses. The term is derived from the Greek word meaning "roused to activity." Hormones of most interest to poultry nutritionists are mainly sex hormones, in particular, estrogenic female hormones or estrogens. They are produced by the ovaries of females just before they begin to lay. The estrogens are responsible for the deposition of fat in muscles, under the skin, and in the visceral and abdominal sections. Industry can now manufacture compounds that have the same effect on the body as naturally-produced hormones.

These substances may display either beneficial or harmful effects in the animal body. Naturally occurring estrogens in plants may be a potential danger to livestock. Subterranean clover had high estrogenic activity due to the presence of isoflavone (genistein). Lush green pastures have long been recognized as having a stimulating effect on milk production possibly due to plant estrogens in rapidly growing forages.

Most of the plant estrogens are the isoflavones whose structural resemblance to diethylstilbestrol is clearly evident. An estrogen, coumestrol, is 30 times as potent as the isoflavones but still much less active than stilbestrol. It is the predominant estrogen of alfalfa and ladino clover, and is widely distributed in leguminous plants.

Estrogens are assayed for potency by determining under standardized conditions the increase in uterine weights of immature or castrated female mice. Legumes, forages, clover and alfalfa, and spoiled grains have received considerable attention but much work remains to be done before the plant estrogens attain their full potential and gain recognition as reliable and beneficial growth factors for livestock and poultry feedings.

Estrogens will fatten birds before they reach sexual maturity and produce a fattening effect on both males and females. Other effects contribute to the value of birds at market time. They stimulate feed consumption in older turkeys and chicken cocks which result in increased weight gains which are economically produced. The number of pinfeathers on the dressed carcasses is also greatly reduced.

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Supplements and By-Products Used in Feeds

PROTEIN SUPPLEMENTS

The major portion of high protein feeds is fed to poultry whose numbers have expanded greatly. The function of high protein feeds is to supply amino acids lacking in cereal grains that are fed in much greater amounts. This is particularly important during growth and egg production when new proteins are being formed; there is less need for them in the feeding of adult animals. High protein feeds are sources of critical amino acids. The increase in supplies of high protein feeds in recent years is due almost entirely to soybeans; production from other sources has remained practically stationary.

Until World War II, a high level of animal protein supplements was considered essential in poultry rations. They were believed to be superior in nutritive value to vegetable protein supplements, perhaps due to something particularly favorable in their amino acid distribution. More recent data fail to support early beliefs. Amino acid analyses do not reveal significant differences between proteins of animal and vegetable sources. Essential amino acids are in both classes of feedstuffs. Proteins of vegetable feeds are somewhat less digestible than those of animal feeds but this is not due to differences between proteins or resistance to enzyme action. Rather the structure of plant material is such that the proteins are enclosed within indigestible carbohydrate walls.

Early failures to be able to substitute vegetable for animal protein supplements were due to deficiencies of minerals and vitamins in which animal feeds are rich, such as calcium, riboflavin, and niacin. Purdue University scientists showed early that soybean meal can serve as the sole protein concentrate in the ration of young chicks and laying hens if corrected by calcium, dehydrated alfalfa meal, choline, and a vitamin concentrate. Animal protein concentrates are not necessary for either high egg production and hatchability or rapid growth of poultry. The deficiency of vegetable protein concentrates in calcium is well known as compared to animal protein feedstuffs. Phosphorus is higher in animal protein concentrates than in vegetable proteins. Thus, there is an increased need for mineral supplementation when plant feeds replace animal feeds. Iodine and manganese additions are also necessary.

The results of many researches establish that the greater effectiveness of animal proteins is not due to their protein or amino acids, but to higher

acids.These are concentrated to "stick" which is usually dried with animal residues. Bones are salvaged as a source of calcium and phosphorus. Proteinaceous material is dried in steam tube driers to meal form to which ground bone is added to produce meat and bone scraps.

Feather meal contains 85% protein but is quite deficient in methionine, lysine, tryptophan, and histidine. It can be used in poultry rations providing consideration is given to amino acid balance in the feed. The high protein content is of particular value in high energy diets.

Blood meal is very high in protein and an excellent source of lysine. It is deficient in isoleucine.

Meat and bone meal is of lower biological value than fish or milk by-products. Excessive amounts reduce performance because of a deficiency of tryptophan. But meat and bone meal is particularly valuable for its contribution of low-cost, valuable phosphorus to the ration. At levels of 2 to 5% of the ration, its addition is usually advantageous. Then, too, meat meal contains fat and this added energy is often bought at little or no added cost.

While tankage and meat scraps are often classed together and produced in one plant, they are not identical in composition. Chief differences are that meat scraps are dry rendered and do not contain blood, except in the tissues. Tankage may be either wet or dry rendered and may contain blood. When meat scraps contain more than 4.4% phosphorus, the word "bone" must appear in the name as "meat and bone scraps." A 50% meat and bone scrap contains 50% protein, more than 4.4% phosphorus, and various other nutrients that are naturally present in meat and bone.

A level of 5% meat scrap in the chicken ration supplies the minimum requirement of vitamin B_{12} for growth. Fat is one component seldom mentioned when the value of meat scraps is considered; it may run as high as 200 lb per ton. A certain amount of fat is essential in the diet. Blood meal has been on the market for some time and at one time was considered one of the poorer protein supplements for poultry feeding. Beef blood protein is a rare example of a protein having a low isoleucine content.

For sometime it was recognized that an unidentified factor in animal protein made its presence felt in poultry feeds. The name "animal protein factor" (APF) was used for some years to designate this unidentified something. It is now known to be mainly vitamin B_{12} which is produced very economically by fermentation. Thus, protein concentrates supply certain valuable "extras" which are an excellent source of the B-complex vitamins and readily available phosphorus. Meat scraps are more variable than fishmeal due to the fact that there are different sources of raw material from which it is produced as well as different methods of cooking and extracting. Amino acid content varies with each different source. Because of this, some feed manufacturers blend several different sources of meat scraps; the more sources, the more uniform the product. It is important to avoid long, high

heat during processing to improve digestibility so that amino acids such as lysine and tryptophan will not be heat denatured and destroyed. Processing techniques are being improved by the packinghouse industry and in the future superior products will be marketed. Perhaps it is too soon to dismiss the nonvitamin B_{12} UGF activity of animal proteins, but before reliance is placed too heavily on such elusive factor(s), some measures of tangible nutritional values must be used in evaluation. In general, the evidence indicates that packinghouse by-products have a place in modern rations when cost of nutrients and results are considered.

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Fish Products

Although the sea covers ¾ of the globe, and living matter is found at all levels down to the great depths of the ocean, it provides only a small part of the food consumed in the world. The present annual harvest is forty million metric tons of fish and fishery products. The most productive fishing areas are the continental shelves, especially in the Northern Hemisphere. Latin America produces 35% of the world's marine catch. Marine fish of 115,000,000 metric tons are potentially available annually, but a large portion is too thinly scattered to be economically harvested. Marine fish account for 4/5 of total production; fresh water species constitute the remainder. The clupeids (sardine, herring, menhaden, and anchovy) contribute 11,000,000 tons and are taken with seines, traps, and weirs. The next largest contribution is groundfish totaling 6,000,000 tons; these inhabit the great offshore fishing banks, such as the Grand Bank of Newfoundland. The most famous of these are the Atlantic cod and the sea basses, fished with otter trawls. Tuna landing is 2.7 million tons and flounder a million tons. To summarize, although the oceans have not yet been fully exploited, marine fish resources are not so vast as some believe. Probably less then 60 million metric tons could be available at present for harvest on an annual basis.

Fish are relatively good sources of many protective nutrients. Properly processed fishmeals are excellent protein supplements, supplying unusually high amounts of the amino acids, lysine and methionine, as well as the minerals, phosphorus, calcium, magnesium, iodine, and vitamin B_{12}, ribo-

flavin, niacin, and choline. Fish oils are rich in vitamins A and D. A major role of fishmeal in poultry feeding is to extend supplies of vegetable protein by providing critical amounts of supplemental lysine and methionine.

Proteins of cereal grains and most other plant protein concentrates fail to supply fully the amino acid needs of poultry due to lack of methionine, cystine, and lysine. Soybean meal widely used in animal feeding is a good source of lysine and tryptophan, but is low in the sulfur containing amino acids. Fish protein is an excellent source of all these amino acids. Fishmeal is decidedly superior to oil meals as sources of essential amino acids, as are meat scraps which outrank oilmeals as a source of lysine, the first limiting amino acid in grains. The limited supply of fish by-products is conserved by using in rations large amounts of the more abundant oil meals. The requirement for essential amino acids grows progressively less as poultry grow older and it is possible to meet needs of mature birds with rations containing less animal by-products and higher levels of oil meals.

Higher levels of fish products are used in Europe than in the United States largely for economic reasons. The actual usage of fish products in poultry feeds is determined by economics, but levels up to 10% fishmeal can safely be used in starting and laying feeds for poultry.

Differences in quality of various fishmeals is due to percentage of protein and fat digestibility. Large variations occur in proximate analysis from species to species, fish of the same species, and from different parts of fish. Protein content of fish averages 19% but varies from 6 to 28%; oil content varies from 0.2 to 64%; ash from 0.4 to 1.5%; and moisture from 28 to 90%. The cause of variation in composition of fish is usually ascribed to such factors as geographical area, and season, but actually, it relates primarily to the feed ingested by the fish, to metabolic rate and mobility of the fishes.

Fish types are classified as to amount of oil and protein they contain. The cod is considered a low oil, high protein fish; mackerel, medium oil, high protein fish; lake trout, a high oil, low protein fish; skipjack tuna, low oil, very high protein; and butterclams, low oil, low protein. Low oil means under 5%, medium oil 5 to 15%, and high is between 15 and 20%.

TABLE 11.1

U. S. FISHMEAL USAGE (1967)

Origin	Tons
United States	200,000
Peru	442,000
Norway, Chile, Canada, Africa	208,000
Total	850,000

The vitamins and minerals of fish vary according to biological factors such as species, age, and anatomical part of the fish. The content of the various B-vitamins in the flesh of fish approximates that in various meats. The content of vitamins A, D, and E is higher in species containing considerable oil. Some visceral organs contain larger quantities of certain B-vitamins and enzymes than the flesh. The muscles of fish and shellfish contain free amino acids. Proteolytic enzymes occur in fish muscle and it is assumed that they play an important role in fish spoilage by degrading fish muscle and furnishing amino acids and peptides for the growth of microorganisms.

Processing techniques affect the stability of vitamins. Fish products lose vitamins due to oxidation during storage. Addition of anti-oxidants will prevent this unless the oil content of the fish is high. Compared to meat, fish and shellfish are good sources of B-vitamins although thiamine, riboflavin, and pantothenic acid are present in less concentration than in meat. Lean fish and shellfish have relatively moderate values for niacin while most other fish are good or rich sources. Fish are good sources of vitamin B_6 and biotin as well as vitamin B_{12}, particularly fat fish and the mollusks. The riboflavin content of fish products is of the same order as dried milk. The niacin content is fairly high. Pantothenic acid and thiamine contents are not high.

Fishmeals marketed in the United States are from menhaden, whitefish, Peruvian anchovies, and herring processed by flame or vacuum drying. The latter prevents overheating which destroys protein, especially lysine. Commercial fishmeals are also manufactured from waste products of the fish filleting industry. The type of raw materials and the method of manufacture greatly influence the value of the products. The composition of fishmeal depends on the raw material while the processing treatment influences protein value. It has been a common ingredient of poultry rations as long as poultry have been fed. A partial explanation of the special nutritive value of fishmeal came with the discovery of the "animal protein factor" (APF) of which vitamin B_{12} was later found to be an important part. But the value of fishmeal is not due to its content of protein and vitamin B_{12} alone. Other known and unidentified growth factors (UGF) are in fishmeal. It is wrong to divide the cost of fishmeal by its protein content and arrive at a cost per pound of protein for comparative purposes.

In the United States fishmeal is used in amounts of 2 to 5% of the poultry ration since vegetable proteins are less costly. In large amounts, fishmeal induces fishy flavor in poultry meat and to a lesser extent in eggs; occasionally there is a significant depression in the hatchability of fertile eggs. Imported fishmeals have been occasionally infested with *Salmonella*.

Condensed Fish Solubles

Condensed fish solubles from the tissue juices of the fish contain a high content of vitamin B_{12} and is a supplement in many vegetable chicken diets. Protein in condensed fish solubles or "stick" (as it was formerly known) is of poor quality; with the exception of lysine, critical amino acids are present in small amounts. The value of fish solubles is not in its protein fraction.

In Scandinavian countries fish solubles are not used as a special ingredient in the ration but dried on the fishmeal which thereby becomes rich in vitamin B_{12}. Fishmeal supplemented with condensed fish solubles is known as "whole" meal and considered the best on the market. If the salt content of fishmeal exceeds a certain low limit, the content must be stated. This results from the use of salt as a preservative on boats that remain away from their base for some time.

Some portions of everything in existence have been discarded into the oceans. Continuous enrichment of the sea and impoverishment of the land has been going on since the beginning of time. The net result is the accumulation of the various elements in the ocean while on land scarcities and depletions of many kinds are encountered.

Cod-liver Meal

This is a by-product of the commercial production of cod-liver oil. Manufacture consists of drying the meal which remains until after oil is extracted from cod livers. Its presence in the ration prevents leg weakness in chicks, but not vitamin A deficiency. During recent years, the production of cod-liver meal has decreased considerably.

Bone Scrap

Bone scrap from fish processing is a valuable supplement to the poultry ration. The high percentages of calcium phosphate contained in it supply major minerals. While its protein content is not high, it is in a form readily assimilated. The iodine content of bone scrap is greater than that of feed from a land source. Oyster, mussel, and clam shells have wide use in poultry feeding and contain from 50 to 200 times the iodine as poultry by-products.

Shrimp Meal

This is made from shrimp waste and has a relatively high content of protein, iodine, and numerous mineral constituents. Shrimp meal is produced on the South Atlantic and Gulf coasts of the United States as a by-product of shrimp canning. Nonedible parts or wastes from this industry

TABLE 11.2

NUTRIENT CONTENT DATA OBTAINED ON MENHADEN (BREVOORTIA TYRANNUS) FISHMEAL

Constituent	No. of Samples	Avg %	Standard Deviation	Standard Error	Coefficient of Variation	Range High	Range Low	Average Decreased 1/2 Standard Deviation %
Lysine	26	4.71	0.31	0.06	6.58	5.52	4.07	4.55
Methionine	26	1.78	0.22	0.04	12.36	2.66	1.48	1.67
Cystine	21	0.56	0.07	0.02	7.41	0.68	0.43	0.52
Tryptophan	24	0.67	0.09	0.02	13.43	1.09	0.69	0.62
Histidine	26	1.43	0.14	0.03	9.79	1.75	1.16	1.36
Arginine	26	3.76	0.27	0.05	7.18	4.42	3.23	3.62
Threonine	26	2.48	0.14	0.03	5.65	2.85	2.31	2.41
Valine	26	3.19	0.17	0.03	5.35	3.48	2.87	3.09
Isoleucine	26	2.71	0.25	0.05	9.23	3.03	1.79	2.58
Leucine	26	4.45	0.26	0.05	5.84	4.98	3.86	4.32
Tyrosine	26	2.04	0.26	0.05	12.75	3.06	1.74	1.91
Phenylalanine	26	2.46	0.13	0.03	5.28	2.74	2.24	2.39
Aspartic acid	26	5.65	0.33	0.06	5.84	6.29	5.17	5.48
Serine	26	2.25	0.15	0.03	6.67	2.60	2.03	2.17
Glutamic acid	26	7.91	0.38	0.07	4.80	8.54	7.33	7.72
Proline	26	2.85	0.20	0.04	7.02	3.44	2.57	2.75
Glycine	26	4.22	0.28	0.06	6.64	4.77	3.89	4.08
Alanine	26	3.70	0.21	0.04	5.68	4.15	3.30	3.59

consist of heads and hulls of shrimp utilized for food purposes and of whole rejected shrimp. They are dried in steam tube dryers and ground into meal. Shrimp meal rates somewhat lower on a protein basis than meat and fishmeal.

Kelp Meal

This is the dried, ground product of the Pacific Ocean kelp. It is chopped, spray dried or run through a vacuum dryer. Little is known of its real feeding value. Its principal use is as a mineral supplement.

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POULTRY BY-PRODUCTS

New York dressed poultry began to disappear from the markets around 1940, due to objections of off-flavors from the viscera. With the marketing of eviscerated, ready-to-cook poultry, the availability of a large and constant supply of offal attracted renderers. They were interested in them as a source of feed protein. The modern trend in poultry processing toward centralization has permitted the recovery of by-products. Wastes from slaughtering are segregated at different points along the line. Blood, feathers, and offal (viscera, heads, and feet) are collected separately and processed into blood meal, feather meal, and poultry meat scrap meal, respectively. Blood and offal are processed into products similar to those from red meat sources. Natural products of keratinous proteins, such as feathers, have little or no nutritional value because of poor digestibility and were an economic liability until a method for converting them into a friable meal for feeding came into use a few years ago.

By-products from broiler chicken and turkey processing total over a half million tons annually. Poultry offal is processed at atmospheric pressure; it is ground, washed to remove dirt and intestinal contents, and centrifuged to remove excess water. It contains 18% protein which is 90% digestible, and 72% water; the remainder is fat. The product is perishable so that it cannot be used in dry feed mixtures but is suitable for mink and pet food manufacturers.

Feathers are steamed under pressure and converted into a friable meal. They used to be spread on land or hauled to dumps but unless they were covered they would blow and develop offensive odors when wet. As received from the poultry processor, wet feathers treated with saturated steam at 40–60 psi for 30–60 min yield a product that can be ground readily after drying. The product has a satisfactory density, can be stored, and remains free-flowing for extended periods without deterioration. The U.S. Dept. of Agr. developed a process adaptable to existing equipment in rendering plants and a public service patent was awarded in 1950. Shortly thereafter, rendering concerns became actively engaged in production of feather meal and patent applications followed. The US Patent Office finally declared that the process was not patentable because of prior use. A large number of firms are engaged now in producing feather meal.

"Feather meal"—officially "hydrolyzed poultry feathers"–results from

TABLE 11.3

FEATHER MEAL

Nutrient Name	Analysis	Units
Metabolizable Energy	1078.00	Cal/Lb
Productive Energy	[illegible]	Cal/Lb
Protein	86 40	%
Arginine	5.60	%
Glycine	6.80	%
Histidine	.40	%
Isoleucine	3.80	%
Leucine	6.60	%
Lysine	1.75	%
Methionine	.47	%
Meth & Cystine	4.80	%
Phenylalanine	3.80	%
Phenyl & Tyrosine	6 20	%
Threonine	4 00	%
Tryptophan	.57	%
Valine	6.50	%
Total Fat	4.40	%
Total Fiber	1.50	%
Calcium	.20	%
Avail Phosphorus	.75	%
Sodium	.70	%
Total Ash	2.80	%
Thiamine	.05	Mg/Lb
Niacin	8.00	Mg/Lb
Riboflavin	.90	Mg/Lb
Panthothenic Acid	3 70	Mg/Lb
Vitamin B-12	39.00	Mg/Lb
Choline	400 00	Mg/Lb
Pyridoxine	2 00	Mg/Lb
Folacin	.10	Mg/Lb
Biotin	.02	Mg/Lb
Potassium	.30	%
Magnesium	.20	%
Pepsin Digestibility	78 50	%

the treatment under pressure of clean, undecomposed feathers from slaughtered poultry free of additives and/or accelerators. Not less than 70% of its crude protein content consists of digestible protein. Actually, hydrolysis makes no more than a minor contribution to the changes resulting from processing.

Feathers are processed in steam-jacketed equipment with horizontal shaft agitation and top and bottom openings for loading and dumping. Jacket pressure is 60–90 psi; internal pressure 30–40 lb; processing time, ½ hr. The load is discharged from the cooker as soon as the pressure is released and fed to a dryer. Agitation breaks up the material and little remains that is recognizable as feathers. After processing and drying, the material has an almost glassy brittleness which makes it easy to grind by impact or hammer mills. A light-colored meal is desired by the feed industry.

Quality of feather meal is evaluated by a 24-hr pepsin-hydrochloric acid digestibility test because it is most closely related to nutritional value. Color, microscopic appearance, friability, and bulk density are used as rough estimates of quality at the time of processing. Cystine is the only amino acid in feathers that is significantly affected by processing with steam. Flight feathers are segregated from body feathers of turkeys and processed separately.

Keratin consists of chains of amino acids joined by peptide bonds formed by a combination of the amino group of one acid to the carboxyl group to the next. A large number of amino acid residues are linked into a single molecule. In their native state, these molecular chains are arranged in an orderly manner, stabilized primarily by hydrogen bonds which can be broken by chemicals or heat, leaving the protein chain free to unfold or unwind in a random manner. When these bonds are broken, the protein loses its original native properties and is denatured. Coagulation and reduced solubility, such as occurs when egg white is heated and loss of enzymatic activity, is typical of denaturation. The great stability of keratins is due to a cystine disulfide cross link, a central bond between two sulfur atoms. The structure of feather keratin may be visualized as extended chains of amino acids bonded together by hydrogen bonds and cross-linked by disulfide bonds.

Steam under pressure causes loss of the organized structure originally present in feathers. There is a chemical loss of cystine, appearance of lantionine, and an increase in susceptibility to enzymatic hydrolysis. If lime is added before processing, arginine, isoleucine, serine, and threonine are lost. Physical change includes increased friability. Pepsin-hydrochloric acid digestibility is too time-comsuming for process control. Changes in color and microscopic appearance give some indication of the extent of pro-

cessing. Commercial feather meal contains 85% protein and supplies over half the protein available from poultry by-products.

POULTRY MEAT SCRAPS

Poultry meat scraps (officially "poultry by-product meal") is made from offal (viscera, heads, and feet) by conventional dry rendering methods. It consists of the "clean, ground, dry-rendered parts of the carcass of slaughtered poultry such as heads, feet, undeveloped eggs and intestines, exclusive of feathers, except in such trace amounts as might occur unavoidably in good factory practice. It contains 16% ash and 4% acid-insoluble ash." Fat is sometimes recovered but added to feather meal to reduce dustiness and add energy. Poultry meat scraps contain 50–60% protein, the quality of which is comparable to that of meat scraps. Poultry blood meal contains 65–70% of protein and is a good source of histidine.

Serious amino acid deficiencies exist in feather protein and its digestibility is poor because of its physical chemical structure. However, feather meal of good quality is a satisfactory substitute for part of the soybean oil meal and cereal grains and gives good results in corn-soybean rations when they are adequately supplemented with sources of methionine. This is not surprising since corn, soybean meal, and feathers are relatively low in this amino acid. The histidine content of feather meal is not available to the chick; possibly other amino acids are also partially unavailable. The failure to obtain maximum growth rates on diets dependent on feather meal protein is due to poor amino acid availability.

Feathers soaked in water during picking, and allowed to accumulate in containers are contaminated with blood and offal components and considerable fermentation develops in the wet mass. As a result, commercial meals contain vitamins and other unidentified factors. Feather meal has been accepted widely by feed manufacturers and found a place as a component of poultry feeds because it contains more crude protein than almost any other practical feedstuff. The protein level of feeds can be altered with a small amount of feather meal, whereas it takes larger amounts of other protein feedstuffs to achieve the same effect. As a result, feather meal allows use of larger amounts of high energy feedstuffs, simply because there is more space left in the formula for energy ingredients. In practice, properly processed feather meal is used to supply ¼ of the crude protein in chick starting rations containing large amounts of protein from soybean meal and corn. When it supplies over ⅓ of the total protein, amino acid deficiency problems arise. When it constitutes ½ or more the deficiencies extend to tryptophan, histidine, arginine, and perhaps other amino acids. Thus, feather meal cannot be used indiscriminately as a protein source. Although it contains some vitamin B_{12}, calcium, phosphorus, riboflavin, and unidentified growth factors, poultry meat scrap and blood

meal have better amino acid balance than feather meal and give slightly better amino acid balance than feather meal and give slightly better results at equal protein levels.

Cooked at sterilizing temperatures, poultry by-products are safe from contamination. Ten percent of feather meal is used in place of soybean and/or fishmeal on a pound for pound basis in the New England College Conference starting ration. Feather meal protein is deficient in methionine compared with soybean meal. Feather meal protein replaces that supplied by 8 lb of soybean meal or 2½ lb of fishmeal with little or no effect on feed efficiency or chick growth. The addition of methionine, lysine, and tryptophan to a starting ration containing feather meal protein does not correct deficiencies. Poultry by-product meal can replace all of the soybean meal in chick starter feeds. In laying hen trials, feather meal protein replaces, with no detrimental effect on performance, proteins supplied by 1.25% of fishmeal, 2½% of meat and bone scraps, and 5% of soybean meal. High-efficiency broiler rations of the University of Maryland include poultry by-product meal at levels from 2.5 to 5%.

The marketability of feather meal and poultry by-product meal depends on a reliable supply. Poultry offal meal is higher in biological availability than meat and bone meal and superior to feather meal as a protein source. Certain batches contain as much as 20% fat, particularly from older hens. Similarly processed feather meal from turkeys or chickens are of equal value. Three percent of feather meal is substituted for other protein in a properly balanced ration without reducing growth or egg production. Feather meal contains an unidentified factor necessary for normal hatchability of eggs.

Small amounts of poultry by-product meal are available but integrated producers process their material and incorporate it in their own feeds. Sufficient poultry feathers are available in the United States for an annual production of 50,000 tons of hydrolyzed feather meal. The addition of 2.5 or 5% of either feather meal or poultry by-products meal to a corn-soybean-alfalfa-type ration supports normal egg production.

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MILK BY-PRODUCTS

Milk products have always been considered important feeds for poultry. They were regarded as a cornerstone on which to build nourishing diets. Liquid milk is a complex mixture consisting of an oil and water emulsion, stabilized by proteins absorbed on the surface of the fat globules. It contains proteins in colloidal dispersion, lactose in true solution, numerous minerals, particularly calcium and phosphorus, fat-soluble and water-soluble vitamins, enzymes, and various organic compounds. Whole milk contains the following: 86 to 88% water; 3 to 5% lipids; 3.2 to 3.6% protein; 4.7 to 4.9% lactose; 0.7 to 0.8% ash; and 62 to 75 Cal per 100 gm. Most lipids of milk are in the fat globules and the surrounding membrane, but small amounts are also in the milk serum. The main proteins are casein and lactalbumin. Casein is in largest amount and occurs as large complex, colloidal particles which contain considerable calcium and inorganic phosphorus plus a little magnesium and citrate. Lactalbumin is insoluble in water and contains sulfur and very little phosphorus; beta lactoglobulins account for 50 to 60% of the total. Lactoglobulins consist of two proteins, euglobulin (true globulin) and pseudoglobulin (false globulin). Each consists of 5% of noncasein proteins and occurs in higher concentrations in colostrum. They carry the antibodies of immunological properties of milk. Milk is a good source of high quality protein because of the quantities of protein present as well as the amounts and proportion of the essential amino acids.

Lactose (milk sugar), the main carbohydrate, ranges in amounts from 4.7 to 4.9% and occurs in 2 forms–alpha and beta lactose. It is about 1/5 as sweet as sucrose, relatively insoluble, and slowly digested and absorbed from the intestine. Its presence in the intestine stimulates growth of microorganisms that produce organic acids and synthesize B-vitamins. These acids check growth of undesirable bacteria and favor absorption of calcium, phosphorus, and magnesium. All the minerals known to be needed for good nutrition are present in milk. It is an outstanding source of calcium and a good source of phosphorus, but a poor source of iron and magnesium, and a variable source of iodine. The content of B-complex vitamins is fairly constant since the microorganisms in the rumen of the cow synthesize these regardless of concentration of vitamins in the cow's diet. Milk supplements in complete feedstuffs make possible a well-balanced and nutritionally adequate diet.

An early investigator in the last century, Gail Borden, developed procedures for producing condensed milk, using low heat in vacuum to prevent incipient decomposition. This product put pure and wholesome milk within the reach of all. America's first commercially successful dry milk plant went into operation in 1903, using an atmospheric dryer and the first spray process of milk drying started in 1906.

Most of the nutritional excellence of fresh whole fluid milk is also present in evaporated and powdered milk. The presence of enzymes in milk was first demonstrated in 1881.

Whey, a by-product of the cheese industry, is produced at the rate of more than 5.4 metric tons annually in the United States, of which ¾ is disposed of as waste, representing 204,000 tons of sugar and 36,000 tons of protein.

Dried whey varies in composition depending on the cheese-making process from which it is derived. There are two types: (1) sweet rennet whey results from the making of cheddar, Swiss or other sweet-type cheese; and (2) cottage cheese whey is produced during the manufacture of farmer, pot, and cottage-type cheeses. Lactose is made from wheys which have not been allowed to become acid. Casein is made from skim or buttermilk by coagulation methods; it contains little fat, ash, acid and moisture. Casein is precipitated from its dispersions by bringing milk to the isoelectric point of casein, by the action of rennet, heating, the addition of alcohol, or the addition of salts. It is a yellowish-white powder, quite stable if dry; if moistened, putrefaction occurs. It is insoluble in water, alcohol, cold dilute acids and neutral organic solvents, but dissolves readily in solutions of the hydroxides or carbonates of the alkali or alkaline earth metals. After the casein is precipitated by rennet there remain two distinct proteins, lactalbumin and lactoglobulin. The latter is identical with blood serum globulin. Coagulation of these 2 proteins leaves in solution organic nitrogen corresponding to only 0.2 gm per liter of milk. This soluble protein is proteose. Lactalbumin is prepared directly from milk by saturating it with $MgSO_4$, filtering and adding acetic acid to the filtrate until it is turbid. Lactoglobulin is obtained by saturating milk with sodium chloride to precipitate casein, filtering, heating the filtrate to 95°F, filtering off the small amount of precipitate formed, and finally saturating with $MgSO_4$. Lactoglobulin is insoluble in distilled water but soluble in dilute solutions of strong acids or bases of inorganic salts.

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VEGETABLE PROTEIN SUPPLEMENTS

Oil meals are by-products from the extraction of vegetable oils from oil-bearing seeds such as the soybean, cottonseed, flaxseed, and peanut. They

comprise ⅔ of the total supply of high protein concentrates available for feeding livestock and poultry and play an important role in the efficient conversion of cereal grains into animal foods.

These amazing results are largely dependent on the availability of oil meals, most particularly soybean meal. Without them it would not be possible to have this performance and obtain present-day supplies of poultry meat and eggs, since they supply the major portion of the supplementary proteins in the poultry rations. Furthermore, the efficiency of conversion of grains into animal foods would be much less. Since the oil meals are regarded primarily as sources of amino acids, they should be conserved for use where these are essential.

Soybean Meal

United States is the world's largest soybean producer raising over 50% of the world's crop, and mainland China produces 30%. Further increases are predicted for the future, because soybeans fit well into most farm programs. They can be grown and harvested by machinery with little labor. It has taken a century to make the transition from the Orient to the United States. The U.S. Regional Soybean Laboratory in Urbana, Illinois has 3,000 strains of soybeans from China, Japan, and other countries of Southern Asia as well as Chile. Their plant breeders are trying to develop the ideal soybean variety for each area of the United States. During the past several decades soybean acreage has increased from 9 to 37 million acres, and production from 300 to 870 million bushels. If present trends continue there may be a crop of 1½ billion bushels by 1975. New varieties with improved disease resistance, resistance to lodging, and higher yielding potential are being studied.

TABLE 11 4

OILSEED MEALS SUPPLY AND DISTRIBUTION, 1968 (1000 TONS)

	Supply				Domestic Use (Feed)
	Stocks Oct 1	Production	Imports	Total	
Soybean	144	13,800	0	13,944	10,600
Cottonseed	106	2000	25	2131	1950
Linseed	14	300	—	314	200
Peanut	3	125	—	128	125
Copra	2	125	—	127	125
Total	269	16,350	25	16,644	13,000

The soybean is the most interesting of the oil seeds. It has been a rapidly expanding culture within the last several decades, principally in the Corn Belt of the United States and in other countries of the Western Hemi-

sphere. Factors which have produced this rapid change are as follows. The soybean is an annual crop admirably suited to mechanized planting, cultivation, and harvesting. Furthermore, soybeans can be handled and stored without much difficulty. Soybeans are milled and oil extracted by hydraulic pressing, continuous screw pressing, or solvent extraction. The use of soybean oil in human foods helps "pay the freight" for the meal in poultry feeds. There are thousands of species of oil-bearing plants, but less than a score account for more than 90% of the fat produced.

The soybean is a native of Asia but has adapted well to American agriculture. *Soja max*, the soybean, is one of the oldest crops; it was in the Materia Medica 4,800 yr ago. A few soybeans were grown in the United

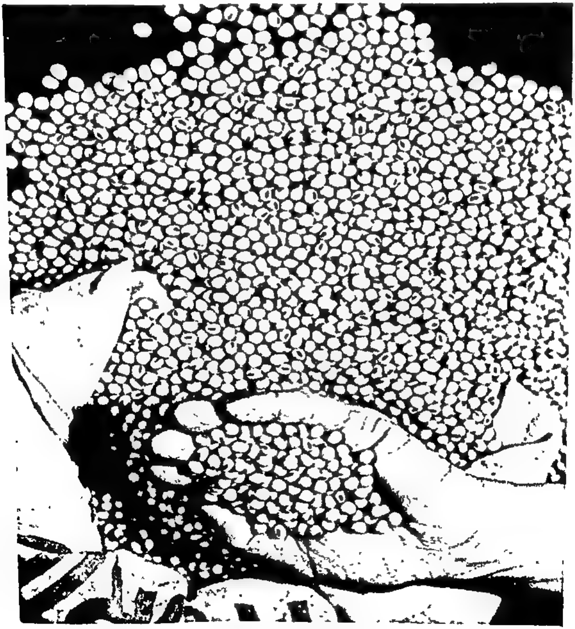

FIG. 11.1. FROM A BOTANICAL CURIOSITY TO A MAIN INGREDIENT IN U.S. POULTRY RATIONS, THE SOYBEAN IN 50 YEARS HAS HAD A SUCCESS STORY UNMATCHED BY OTHER FEED INGREDIENTS

States as botanical curiosities prior to 1907. Many different varieties were collected from the Orient and tried experimentally. The soybean is a summer, leguminous annual with pods 1 to 1.5 in. long containing 2 to 4 seeds. The seeds, when mature are yellow, green, brown or black and some are round, some oval, and some flat. Large and abundant root tubercules permit this plant to build up the fertility of the soil. The plant grows from 2 to 6 ft in height; flowers are small, sweet-pea shaped, white or purple in color.

Soybean Oil

Soybean oil was first produced in California about 1910 with beans from Manchuria. Production from domestic seed started in North Carolina in 1916 and about 1920 in Illinois, using expellers. Soybeans are grown nearly everywhere that corn or cotton is grown. Soybean meal is valuable because of its high biological value protein, its substantial fat content, and an impressive list of carbohydrate and inorganic constituents. Soybeans contain several enzymes which are inactivated if the bean is heated over 122° F and are, therefore, not present in properly cooked soybean meal.

Five protein fractions have been isolated from soybeans by fractional precipitation at different concentrations of ammonium sulfate. Glycinin is the principal protein and its amino acid content is similar to casein.

Varieties of soybeans are very numerous. Those grown in the United States are divided into three general groups: grain, vegetable, and forage. For commercial seed production, varieties are yellow-seeded and used largely for processing for oil, meal, and flour. The varieties used for forage and green manure are the black and brown-seeded varieties which for the most part are low in oil. Vegetable varieties for human food are used solely as a green vegetable or dry edible soybeans. Soybeans, like other legumes such as clover, alfalfa, peas, and beans are able to utilize the nitrogen of the air through the action of bacteria on the roots. The presence of these organisms is indicated by the development of nodules or tubercules on the roots. Inoculation is effected through the use of pure cultures of soybean bacteria or by the application of soil from a field where well inoculated soybeans were grown the previous year.

Harvesting and Storage

Soybeans are combine-harvested and millions of bushels are harvested over a period of a few weeks. Soybeans store well in bins of steel, wood, plywood, insulation board, and other materials, as long as the bins are weather-proof. Accumulation of moisture does not affect the beans unless the moisture content is 13% or above. Commercial grain elevators play an important part in the buying and selling of soybeans in America. They are classified according to the type of business done and include: (1) country

elevators; (2) terminal elevators, and (3) mill elevators, operated in conjunction with milling and processing plants. Elevators stress arrangements for receiving, elevating, weighing, cleaning, drying, distributing, storing, and shipping. They handle all operations with a minimum of labor and power.

Large storage bins are usually circular in shape with a depth several times bigger than the diameter and are of reinforced concrete construction. The storageability of soybeans is affected by prior history of the beans, as well as conditions prevailing during storage. The degree of maturity at harvest and the methods of harvesting and handling up to the time the seed is placed in storage are important. Certain biochemical changes occur in soybeans as a result of storage.

Moisture is the most important factor promoting deterioration of stored beans. Translocation of moisture in bulk stored beans can cause concentrations of 16 to 19% moisture in the upper parts of the bin when soybeans are stored at a uniform moisture content of 12%. Microorganisms are the agents responsible for the deterioration of stored soybeans having moisture contents above critical limits. Injury to outer coats of seeds provide access for fungi to the nutrients of the endosperm. The molds, *glaucus* and *aflavis*, proliferate on soybeans stored at high moisture content and are observed in soybeans with 14% moisture after storage for two weeks at about 75% RH in the surrounding atmosphere.

Spontaneous heating in grains is a direct consequence of respiration under conditions *which do not permit rapid dissipation of the involved heat.* At high moisture, many types of molds, yeasts, and bacteria undergo active proliferation. It is not usual in commercial practice, however, to store beans having moisture contents of these magnitudes. The only means for the prevention of deterioration of damp seed crops in storage is to dry them to a safe moisture level. Storage of grain under an inert atmosphere or one deprived of oxygen for the purpose of inhibiting damaging chemical and biological changes in the seed is possible but not practical.

Solvent Extraction

Soybean continuous solvent extraction plants were brought to the United States in the 1930's from Europe. Preparation of soybeans for solvent extraction is as follows: soybeans are cracked, dried to 8–11% moisture content, and heated to 140°–160°F. While the cracked soybeans are still hot and slightly plastic they are passed through flaking rolls. Steam is added at the rolls so that the flakes hold together and thus produce less fines. Combined steps of drying, steaming, and heating prior to flaking is termed tempering or conditioning.

Soybean flakes are very fragile so that they are usually transported to

the extractor in drag length conveyors, so they move without tumbling, which might happen in screw conveyors, or bucket elevators. The extraction systems operate at atmospheric pressure so that seals are unnecessary. Three materials enter the extractor, namely, flakes, solvent and air; three products emerging from the extractor are mixtures of oil meal, solvent with oil, and solvent vapors. Each of the latter requires treatment to separate the solvent. Meal dryers or desolventizers are the three general types: (1) horizontal steam-jacketed; (2) vertical direct steam; and (3) recyclization. The horizontal jacketed dryer has a central tubular shaft on which are fastened radially projecting arms with progressing paddles fastened to the ends of the arms. Steam is introduced into the tubular shaft to increase the heating surface of the vessel. Direct steam is introduced near the bottom of the bank of dryers to displace the solvent vapor and allow complete effusion of solvent from the flakes.

In the case of solvent extraction, the maximum temperature at any stage of the process rarely exceeds 220°F. Although the meal is subjected to cooking action, very little browning occurs. Consequently, solvent-extracted meal is "toasted" at 250°–260°F at which temperature denaturation of the protein occurs and partial carmalization of the carbohydrates produces the golden-brown appearance. These flakes contain 25% of the material that will pass through 16-mesh screen. Flakes and hulls which do not pass the screen travel to the first grinder where they are subjected to reduction.

Soybean meal finds a ready outlet for use in poultry rations and thus finds its way to feeders via the feed manufacturer. Perhaps more than anyone else, the feed manufacturer has stressed the need for balanced rations and proper heat processing of soybean meal.

Soybean meal or soybean oil meal as it was originally called, refers to the ground residue that remains after processing soybeans to extract most of the oil that they contain. Where raw soybeans are ground, the product is called ground raw soybeans, not soybean meal. In nonruminants or animals with a single or simple stomach, raw soybeans are not satisfactory. Growth and metabolism trials at the University of Wisconsin showed that the application of heat to raw soybeans caused an increase in the availability of certain fractions of the protein molecule.

Effect of Heating Soybeans

Heat causes the methionine-cystine fraction to become available so it can be utilized by the animal. Autoclaving soybeans increases the nutritional value of the protein fraction much in the manner as cystine-methionine supplements raw soybeans. The rate rather than the extent of liberation of methionine in soybean protein determines its biological value. Nebraska

researchers have noted a trypsin-inhibiting substance in raw soybeans which can be extracted with water or dilute acid at pH 4.2. The substance has a proteolytic-inhibiting effect and reduces the growth of chicks. The material has been crystallized, characterized, and found to be a stable protein of the globulin type with an isoelectric point of 4.5. Improved nutritional values of soybean protein in raw flakes result after thorough washing with water and draining off the water extract.

No improvement in nutritive value of protein in soybeans occurs from extracting them or defatting them with ether, hexane, carbon tetrachloride, benzene or ethanol. Autoclaving soybeans has been the most practical method of improving nutritive value but autoclaving for too long or at too high a temperature impairs its nutritive value. The material should not be overheated. The importance of proper cooking of commercial soybean meal is apparent in the case of meal that is to be used as a substantial source of protein in rations where rapid and efficient growth is a primary objective.

Tests for Nutritive Value

There are several tests to determine the nutritive value of the protein in soybean meal. If the material is soluble in water or has urease activity, it shows it has not been denatured and, therefore, not heated sufficiently. All vegetable protein concentrates including properly cooked soybean meal require supplementing by UGF for good growth of birds with critical protein requirement. Until UGF was isolated and concentrated making it possible to supply it when testing combinations of protein in soybean meal, it was difficult to distinguish the effect of protein supplementation caused by addition of soybean meal.

Nutritive Value

Soybean meals are well fortified with essential minerals compared to grains and many feed by-products. However, when soybean meal replaces concentrates of animal origin, it is advisable to make up any mineral deficit caused by this change in the formula. Fifty to seventy-five percent of the phosphorus in soybeans is in the form of phytin which chicks are unable to utilize because they lack the enzyme, phytase, in the alimentary tract. Thus, use sufficient inorganic phosphorus to bring the level up to 0.2% in the poultry rations containing soybean meal.

Soybean meal is a fairly good source of the vitamins of the B-complex in comparison with grains and grain by-products. Since thiamine is unstable to heat, it is present in only variable amounts in soybean meal, depending on the severity of the heat treatment. A ration composed largely of corn and soybean meal is deficient in riboflavin, pantothenic acid, and niacin.

Goiter is produced in chicks on rations containing 25% soybean meal. The goitrogenic factor of soybeans is partially inactivated by heat and iodine counteracts the effect on the thyroid gland. The goitrogenic tendency of soybean meal is of no particular economic importance, since practical poultry rations containing soybean meal and iodine produce perfectly normal poultry. Soybean meal is decidedly superior to ground or whole soybeans and at least equal to cottonseed meal for growing birds. Soybean meal with sufficient added minerals is about equal to meat scraps and fishmeal and somewhat better than gluten feed or cottonseed meal in rations for chicks. Protein per se is not needed as a supplement to soybean meal in chick starter rations provided they contain essential minerals and vitamins. A combination of properly heated soybean meal and grains supplemented with minerals and vitamins, including UGF, supplies protein as high in quality as any combination that can be provided. Raw soybeans are definitely inferior to properly cooked soybean meal as protein supplements in chick starter rations. As stated, soybean meal serves as a protein concentrate in laying rations, but it should not be in excess of 50% of the supplemental protein. The remainder should consist of fishmeal and meat scraps.

Soybean meal in rations for laying hens does not cause an objectionable discoloration of the yolks of the eggs when stored, as is the case of cottonseed meal. Satisfactory hatchability of hens eggs is obtained where rations contain soybean meal as a principal protein supplement. Soybean meal has been successful in starter and growing rations for turkeys when properly processed. It generally excels all other vegetable protein concentrates in starter mashes fed to chicks up to eight weeks of age when used as a principal protein supplement in rations otherwise adequate in essential minerals and vitamins. Best results are obtained when soybean meal is used at high levels and supplemented with fishmeal which supplies UGF (present in liver meals and extract), condensed fish solubles, and various milk derivatives. When properly fortified with vitamins, minerals and essential growth factors, soybean meal is satisfactory in turkey starter and grower rations.

Early work showed that soybeans fed to rats as a sole or a principal source of protein in an otherwise complete ration did not support growth. However, normal growth resulted when they were fed soybeans previously cooked. The low nutritive value of the protein of raw soybeans is said to be due to a deficiency of the amino acid, cystine. Unfortunately, raw soybeans interfere also with fat digestion; this is overcome as birds become older. Soybeans can be improved either by heating the beans or pelleting them. Pelleting the entire diet is more effective than pelleting the soybeans alone.

Laying Rations With and Without Animal Protein

A recent test compared laying rations with and without animal protein. Proportions of ingredients were adjusted so that two rations were equal in calories, protein, calcium, and phosphorus values. The control laying ration contained 3% of meat and bonemeal, 2% fishmeal, 1% dried whey, and 2% tallow. The "all plant" ration still contained tallow which has no value apart from the calories. The production period was 350 days; average egg production of hens on the control (fish, meat) ration was 230, and on the "all plant" ration 234. Egg size and shell quality were slightly superior on the "all plant" ration. No differences were found between the rations on feed consumption, mortality, and body weight. This test proves that for laying birds there are no values inherent in animal protein that cannot be obtained with "all plant" proteins.

Soybean Storage Effects

The effects of six months storage on soybean protein include a progressive decrease in: true protein content, solubility of protein in salt solution, and in digestibility of protein. Greater changes occur in meal stored in bags than sealed jars, and in low-fat than high-fat samples. The storage of soybean meal results in partial denaturation of the proteins, as indicated by their decreased solubility in salt solution, as well as proteolysis. Soybeans have a higher mineral content than many common legumes and grains—4 times as much potassium and sodium, 5 times as much calcium, 3 times as much magnesium, and 2 times as much phosphorus as wheat. A high percentage of the iron contained in soybeans is available. A Wisconsin study indicates that the percent available iron in certain feedstuffs is as follows: soybeans 80, pork liver 66, spinach 20, and alfalfa 27. For maximum performance of poultry from the standpoint of growth and egg production, cereal grains and their by-products should be supplemented with feeds high in protein. Properly cooked soybean meal is highly efficient in this respect and is progressively replacing much animal protein in poultry rations. Its use in combination with animal protein concentrates produces rations of high biological efficiency at low cost.

Soybean Oil

Soybean oil stands midway between cottonseed oil and linseed oil in edible and drying characteristics. It has an unsaturated fatty acid content second only to linseed oil; ½ is linoleic acid, ⅓ oleic acid, and ⅙ divided among palmitic, linolenic, arachidonic, and lignoceric acids. It has an iodine number of 120, unsaponifiable matter 1.5%, free fatty acids 1.5, and break 0.6%, smoke point of 280° F, and a flash point of 589° F.

Soybean oil is a most versatile oil. Phosphatide content of soybeans

varies from 1.6 to 3.0%. Lecithin contains choline as an organic base and constitutes 38% of the phosphatides; it is linked with carbohydrates in glucoside-like compounds. The colloidal nature of lecithin contributes largely to its emulsifying properties which are applied in the paint, soap, cosmetic, and food industries.

Soybean Enzymes

Soybeans have two special enzymes, urease and lipoxidase. Urease converts urea of ammonium and carbon dioxide, and is used in a test for amount of soybean flour addition to products such as sausage. Lipoxidase catalyzes oxidation of unsaturated fatty acids with the production of peroxides which interact with other compounds. This enzyme is important wherever the storage stability of fats is involved. Lipoxidase is not widely distributed in nature.

Raw soybeans have to be limited to a level of 7% of the laying mash. They are a good source of energy as well as protein for chicks. Some means of increasing oil availability is essential if they are to be used to the fullest advantage, i.e., flaking soybeans or pelleting diets. In some years, there are economic advantages in using soybeans as such, but in most years there are advantages of extracting and selling the oil separately.

Cooked, unextracted soybeans have been tried. Factors in favor of leaving oil in the meal are the rather large amounts of caloric value that the oil contains over that in feed grade fats, namely, 4,172 Cal of metabolizable energy per pound compared with 3,230 Cal for feed grade tallow. Most oil in soybeans is in the matrix of the feed particle rather than sprayed on the outer surface as in the case with added fat.

There are no simple and quick chemical or physical tests which soybean processors can rely upon to produce meals of optimum nutritional quality. Actual feedings tests are the ultimate criteria but certain correlated chemical-physical tests can be used as a rapid and simple tool for checking quality on a daily basis.

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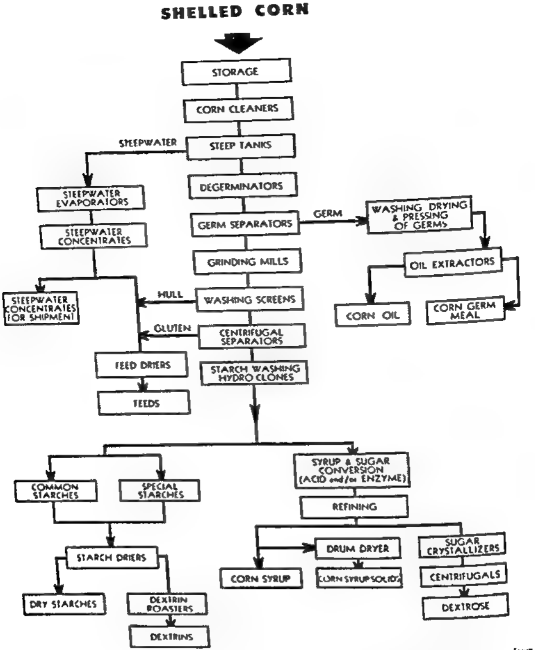
Corn Gluten

Corn oil is a by-product of three processing industries. Starch, corn syrup, dextrose, and dextrin are the principal products from the wet milling of corn whereas, corn gluten meal, corn gluten feed, and corn oil are by-products. Cornmeal and hominy grits which consist mainly of the endosperm without separation of starch from gluten, are made in the dry milling of corn. Processes and machines resembling those used in the milling of wheat flour are used. The quantity of oil produced per bushel of corn is less than half that by wet milling. Strains of corn can be bred to have as much as 12% fat, concentrated mainly in the germ (embryo). The corn kernel consists of 81% endosperm, 11% germ, and 7% bran. Of the oil in the whole kernel, 84% is in the germ and 14% in the endosperm.



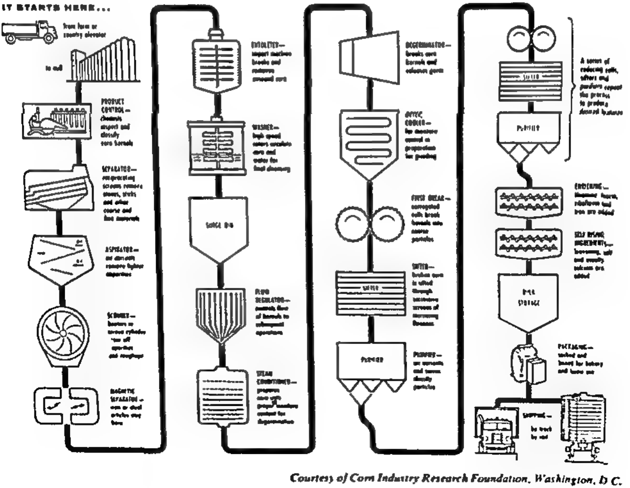
Courtesy of Clinton Corn Processing Co., Clinton, Iowa

FIG 11.2 SCHEMATIC OUTLINE OF THE CORN WET MILLING PROCESS

Wet Milling of Corn.—In the wet milling of corn, grain is cleaned by a series of screens and air separators and steeped in water containing 0.2% sulfur dioxide for 48 hr at about 130°F. The grain swells and softens; the steeping operation removes most of the water-soluble materials including sugar, some proteins, and minerals. The solubles are recovered by con-

centrating the steepwater and mixing it with gluten, or using it as a nutrient in the manufacture of antibiotics, or as a feed supplement (corn fermentation solubles). Steepwater contains phytin which can be precipitated as calcium phytate by the addition of lime. The steeped grain passes through degerminators which break up the grain and loosen the germ without disintegrating it. It drops into the separators consisting of troughs in which the germ floats on thin slurries of starch and overflows at one end. The dried germ contains 50% oil which is pressed from it.

Dry Milling of Corn.—In the dry milling of corn, the grain is passed through rolls, reels, aspirators, and sifters for gradual reduction of the grain to smaller particles and separation into fractions rich in bran, germ, and endosperm. The corn is first cleaned by a combination of screens and aspirators and mixed with warm water to bring it to a moisture content of 21–24%. The grain is held in a tempering bin 1 or 2 hr before going to the degerminator rolls. The degerminator breaks up the grain and loosens the germ without much grinding action upon the germ itself. From the degerminator, the broken grain passes through dryers which remove part of the moisture, through reels to make a rough separation of sizes, to aspi-



Courtesy of Corn Industry Research Foundation, Washington, D.C.

FIG. 11.3. A SIMPLIFIED DIAGRAM SHOWING HOW CORN MEAL IS MILLED

rators where the bran is removed, and then through a series of rolls, sifters, and aspirators. The germ produced in this way contains 20 to 21% fat which is recovered by passing the germ through scoop presses which reduce the fat content of the cake to 4 or 5%.

Corn Gluten Feed.—This consists of the corn gluten meal and corn bran, with or without corn solubles. Its protein is not of high quality and, therefore, is not used as the chief protein supplement for poultry. It is a concentrated feed, higher in digestible nutrients than soybean meal, higher than yellow corn in vitamin A but lower in calcium, phosphorus, and riboflavin. It replaces half of the meat scrap in poultry rations if plenty of calcium, phosphorus, and riboflavin are provided. It increases the yellow color in the shanks of skin of chickens and in egg yolks. It is a good source of xanthophylls for pigmentation.

Corn Oil Meal

This is used in certain poultry rations because of its high water-absorbing capacity. In combination with other supplements, it furnishes protein of better quality. Corn molasses or *hydrol* is a by-product in the manufacture of corn sugar from corn. It is higher than cane molasses in sugar, extremely low in protein, and about equal to cane molasses in feed value.

An important component of corn oil is tocopherol which keeps the oil from oxidizing rapidly in spite of its large content of linoleic esters. It amounts to 0.1% of the weight of the oil.

Cottonseed Meal.—This is a by-product rather than the primary product of the cotton plant. It is geared to the production of cotton fiber and has only 1/6 its value. Principal cotton-producing areas outside the United States are India, USSR, Brazil, China, and Egypt. Cottonseed oil is an important edible oil and methods for processing are similar to those used for other oil seeds, except that the seed has to be cleaned as in the case of cotton seeds which have a fuzz. Cotton seeds are delinted to remove the fuzz.

Four types of cottonseed meal, totaling 2.8 million tons, are produced annually. Screw pressed (expeller) meal accounts for 60% of the total. Direct solvent (hexane) and prepressed solvent meals each account for approximately 20% of the total. Hydraulically processed cottonseed meal comprises less than 3%. Cottonseed meal contains: (1) oil, (2) free and bound gossypol (yellow polyphenolic pigment), (3) available amino acids such as lysine, (4) protein, and (5) fiber. Free gossypol values are lowest in screw pressed and prepressed solvent meals with highest values in direct solvent meal. Most gossypol is removed, either lost or bound.

Gossypol in Cottonseed Meals

The protein and fiber contents of cottonseed meals are inversely related. Large amounts of cottonseed meal are used in broiler and turkey feeds. There is considerable variation in oil, fiber, moisture, and protein quality of cottonseed meals and thus significant differences in energy can be expected. There is a low availability of lysine but tryptophan and methionine plus histine showed excellent availability. There is a need for lysine supplementation of many cottonseed meals when used in rations for growing poultry. Since the beginning of this century, it has been known that cottonseed meals contain gossypol which has a poisonous effect when fed to livestock and poultry. The toxicity of cottonseed to nonruminants is related to the amount of free gossypol present in the cottonseed. Gossypol is present in the native cottonseed in many small pigmented glands. This gives cottonseed its characteristic color. Free gossypol is toxic. Bound gossypol reduces growth rate in chicks when fed at high levels, but there are also other factors in cottonseed which inhibit growth. High temperature cooking is the oldest and most widely used method for releasing free gossypol from the glands. After the gossypol is released, it is either removed or inactivated to make it nontoxic. Cottonseed meal with free gossypol levels below 0.04% is tolerated by chickens.

TABLE 11.5

PERCENT COMPOSITION 50% PROTEIN COTTONSEED MEAL

Crude protein	50.00	Histidine	1.31
Crude fat	1.00	Leucine	3.00
Crude fiber	8.00	Isoleucine	1.88
Ash	7.00	Phenylalanine	3.05
Nitrogen solubility	75.00	Threonine	1.77
Calcium	0.20	Valine	1.78
Phosphorus (total)	1.40	Metabolizable energy Cal per Lb	1010.0
Phosphorus (available)	0.40		
Free gossypol	0.03		
Arginine	5.00		
Lysine (total)	2.15		
Lysine (epsilon amino)	1.90		
Methionine	0.77		
Cystine	1.04		
Tryptophan	0.56		
Glycine	2.50		

Very low levels of free gossypol causes discoloration of egg yolks when the eggs are put into cold storage. Small quantities of gossypol are transferred to the egg and a slow chemical reaction occurs between the gossypol and the components of the egg yolk resulting in the darkening of the egg yolk during cold storage for extended periods. Cottonseed meal may constitute 50% of the protein source in chick and broiler rations if the dietary

level of free gossypol is less than 0.01%. Some cottonseed meals furnish a sizable portion of the protein in laying hen rations, if the resulting eggs are not stored. The effect of gossypol, the yellow polyphenolic pigment present in cottonseed pigment glands, upon the color, weight and production of eggs is dramatic. Free gossypol is believed to be the major biologically active form but bound gossypol may be released in the digestive tract.

High levels of gossypol in poultry rations depress weight, feed intake, and feed efficiency; many times there is increased mortality and depressed hatchability of eggs. Additional deleterious effects are enlarged gall bladders and blood and bone changes. Substances are also present in cottonseed that produce pink-white discoloration, the cause of which the author has shown to be a reaction of conalbumin of egg white with iron diffused from the yolk. The primary chemical entity responsible for the pink-white is a cyclopropenoid ring. The intensity of pink-white is governed by factors such as the length of feeding period, storage temperature, and amount of cyclopropenoid ingested. An accompanying effect is increased levels of stearic acid, and decreased levels of oleic acid in egg yolks which makes a stiffer yolk substance. Pink-white discoloration is usually accompanied by enlarged salmon-colored yolks. The author found this to be due to the migration of conalbumin into the yolk due to relaxation of the vitelline membrane. Here it is combined with the iron of the yolk to produce a salmon-pink color.

In future years, there is a likelihood of further development of glandless cottonseed which does not contain gossypol but does have fatty acids. Improvement in oilseed processing and increased knowledge of the biological effects of specific cottonseed components have led to increased usage of cottonseed meal in nonruminant rations. Development of the glandless cottonseed meal and new types of solvents for oil extraction are expected to lead to further improvement in cottonseed meal in the years ahead. At the end of World War II, 95% of the domestic cottonseed meal was produced by hydraulic processes and relatively little screw-pressed or solvent meal was available. All commercial cottonseed meals in rations are better for young growing animals when supplemented with L-lysine; when animals become older, there is less need for this amino acid. After lysine needs are met in broiler rations, the most limiting amino acids in cottonseed meal are methionine, threonine, isoleucine, and leucine.

The amount of cottonseed meal used in formula feeds amounts to 1.1 million tons annually or slightly more than ½ of the cottonseed meal produced. When prices are equal on a protein basis, soybean oil meal is used in preference to cottonseed meal in rations for chicks.

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Other Oil Meals

Some plants which produce oil are of relatively minor importance in the United States, but are high on the list of world sources. Peanuts, for example, are grown and used in much greater quantity in other parts of the world to produce peanut oil and meal. Coconut oil is exported from countries where it originates together with *dried coconut* meal in the form of *copra oil meal.*

Coconut Oil Meal.—Coconut oil meal is a by-product from the production of oil from the dried meats of coconuts, the nuts of the coconut palm. It is made by the hydraulic or expeller process and contains less protein than corn-gluten feed. Its protein is of better quality than that in corn gluten but not soybean meal. It should not be fed as the only protein supplement to poultry; it should be supplemented with some animal protein. Limited amounts of corn meal are included in poultry rations when sufficient protein of better quality is provided. A level of 2 to 5% coconut meal is used in poultry rations on the Pacific Coast. A light-colored oil meal is preferred to a dark meal. The dark meal results from too high a temperature in expressing the oil and this reduces digestibility.

Babassu Oil Meal.—Babassu oil meal is produced from the hard-shelled seed of a Brazilian palm. It is similar in appearance and composition to coconut oil meal but a trifle higher in protein. It satisfactorily replaces 10% of the grain in poultry feeds.

Rapeseed Oil Meal.—Rapeseed oil meal is the by-product from the production of oil from rapeseeds. It has varying amounts of glucosides from

which mustard oils are formed in the digestive tracts of animals under certain conditions. These are irritating to the digestive system and can cause serious problems. It must be fed very carefully to avoid injurious results; not over 10% is used in poultry rations.

Navy Beans.—Since 1920, it has been known that raw navy beans are injurious to animals and that autoclaving destroys this injurious effect. They also contain heat-labile trypsin inhibitors and hemagglutinin which are toxic to chickens. Sulfur-containing amino acids are the most limiting amino acid of navy beans, but raw beans do not support growth even when supplemented with all the amino acids in which the diet is deficient. Also, growth of animals not receiving raw bean diets is depressed by the addition of trypsin inhibitors from raw beans. The low nutritive value of raw navy beans is due to a methionine deficiency and the presence of a heat-labile toxic factor. When beans are autoclaved, and supplemented with methionine, growth is as good as on the casein diet.

Velvet Beans.—These are grown as a soil improving crop in the United States and often used as a livestock feed. These beans are toxic to pigeons; on the second day of feeding, birds show ruffled feathers and appear sleepy. Mortality commences on the fourth day. Feeding of diets containing velvet beans decreases performance of chicks as measured by mortality and reduced body gains; there is also decreased performance of laying hens. There is some factor in the beans that interferes with normal growth and egg production in chickens.

Mung Beans.—These are sometimes used as a poultry feed. Each year split and broken mung beans become available and are used in poultry feeds. They are ground and used in place of soybean meal in poultry rations and also fed as a part of the scratch grain mixture. Satisfactory egg production and hatchability are obtained when ground mung beans were fed as a source of vegetable protein. They have no detrimental effects on egg quality when fed as a source of protein in laying mashes for hens.

Sesame Oil Meal.—Sesame oil meal is a by-product from the production of oil from sesame seeds which are raised in tropical countries. It contains as much protein as cottonseed meal and is high in calcium and phosphorus. Its protein is of good quality. It is satisfactory for poultry feeding and supplements the protein of soybean oil meal for chicks. Sesame oil meal is deficient only in lysine which is well supplied by soybean meal.

From 0.4 to 0.5% lysine is necessary to achieve optimum growth and conversion. Combined with soybean oilmeal, sesame meal results in better chick growth than all-sesame rations.

Safflower Meal.—Decorticated safflower meal was first used in 1947. Research since that time shows that when adequately supplemented with lysine, safflower meal rations give equivalent gains in growing chickens and

TABLE 11.6

NUTRIENT COMPOSITION OF DECORTICATED SAFFLOWER MEAL

Proximate Analyses		%
Crude protein		42.0
Fat (ether extract)		0.5
Crude fiber		15.0
Ash		8.0
Moisture		10.0
NFE		24.5
Energy (Poultry)	Cal per Kilo	Cal per Lb
Metabolizable	1700	770
Productive	1190	540
Essential Fatty Acid		%
Linoleic acid		0.3
Minerals		%
Calcium		0.4
Phosphorus (total)		1.3
Phosphorus (available)		0.4
Sodium		0.04
Chlorides		0.16
Potassium		1.2
Magnesium		1.2
	Mg per Kilo	Mg per Lb
Manganese	40	18
Zinc	185	84
Iron	990	450
Copper	88	40
Cobalt	2.0	0.9
Amino Acids		%
Arginine		3.7
Lysine		1.3
Methionine		0.69
Cystine		0.70
Tryptophan		0.60
Histidine		1.0
Leucine		2.6
Isoleucine		1.7
Phenylalanine		1.85
Tyrosine		1.05
Threonine		1.35
Valine		2.3
Glycine		2.4
Vitamins	Mg per Kilo	Mg per Lb
Riboflavin	2.3	1.1
Pantothenic acid	39	18
Niacin	22	10
Choline	3260	1480
Folic acid	1.6	0.7
Pyridoxine	11.7	5.3
Thiamin	4.6	2.1
Biotin	1.7	0.76

turkeys compared to good control rations. Feed conversions are the same when rations are isocaloric. Decorticated safflower meal has given egg production similar to soybean meal controls, used at levels up to 15% of the rations. Feed conversions are also equivalent to the controls when feeds are isocaloric. Decorticated safflower meal has a metabolizable energy value of 774 Cal per lb.

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Fermentation Products

INTRODUCTION

Three important vitamins are produced by fermentation. Riboflavin and vitamin B_{12} are made directly by fermentation. Vitamin C (ascorbic acid) is derived from sorbose which is produced by a bacterium that feeds on sorbitol, prepared from sugar. Vitamin D is manufactured by ultraviolet irradiation of ergosterol, a substance obtained from yeast. Mass-produced vitamins are now used to accelerate the growth and protect the health of livestock and poultry. This puts more meat and eggs on the table at less cost. One of the most far-reaching of all scientific achievements has been the ability to harness microscopic creatures in the service of mankind which made possible the fermentation industry. By learning how to control some of the microbes, animal production has entered a new era of health and longevity. The manufacture of alcoholic beverages and the art of cheese-making involve fermentation and were discovered by ancient man without even knowing that microorganisms existed.

Modern science not only has gained mastery over some of the organisms but has discovered numerous useful new ones. They are bred like prize cattle, wheat or roses, and every phase of their amazingly useful productive lives are carefully governed. Bread and wine, almost as old as agriculture itself, have been used in some form virtually everywhere on earth. The first to suggest that microorganisms cause fermentation was a French scientist, Thenard, who showed that yeasts used by winemakers were alive and responsible for the formation of alcohol. His views were at first rejected but finally upheld. Science entered a new era when the immortal Louis Pasteur arrived on the scene. An innovator with great courage and determination, he showed that diseases which were killing silkworms and thus harming the French textile industry were caused by microorganisms, and that similar organisms were responsible for diseases of animals and humans. This was one of the great turning points in the history of civilization.

BREWERS' FEED

Actually, converting barley into beer is more complicated than most suspect. Just one step—transformation of glucose into alcohol and carbon dioxide involves 14 different chemical reactions and many enzymes and coenzymes. Yeasts used in brewing are tireless microbes capable of synthesizing their cell substance from relatively simple elements and com-

pounds. Brewers learned early the value of pure cultures of yeasts instead of mixtures of the numerous types found in nature. The good types were selected and "bred" to produce the kind of end products desired.

From the brewing process, products are recovered which are valuable in animal nutrition. The yeast cells are dried as well as the grains and malt sprouts; this stabilizes them and enhances their digestibility and assimilability. It also transforms them into free-flowing granular products, particularly suited for easy blending and distribution in other feed ingredients.

Since breweries are modern, sanitary plants, situated away from animals, brewers' feeds are made and kept free of the contamination certain natural products acquire during production and distribution. This is particularly important to the feeder and feed manufacturer in disease prevention.

The raw materials of brewers are grains purchased from U.S. farmers via the brewery malt house. Brewers extract the starchy portions of the grains for their brews, thus concentrating the more valuable nutritional factors to about ⅓ of the weight of the original grains. These are marketed in the form of several brewers' feeds, yeast, grains or solubles.

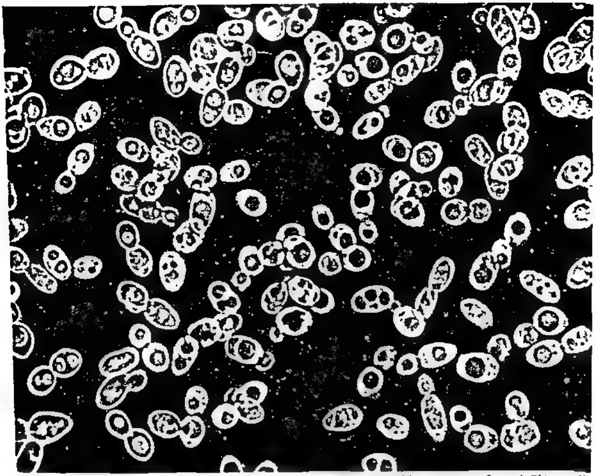
The nutritional value of these feeds is superior in many ways to that of the raw materials going into their production. During fermentation, the yeast absorbs much of the thiamine and less of riboflavin and other B-complex vitamins from the wort. As a result of enzymatic action, enriched feeds of great uniformity are returned to farmers, usually as concentrates from feed manufacturers to help balance nutritionally the plentiful and economical farm grains and roughages.

Over a million bushels of barley and large amounts of corn and rice are processed annually by U.S. brewers. A bushel of barley produces 14 lbs of brewers' dried yeast. This represents a very substantial contribution in terms of essential protein, carbohydrate, minerals, and vitamins to U.S. livestock nutrition and health, particularly as protein and high-vitamin feedstuffs.

Brewers' Dried Yeast

What is brewers' dried yeast? Even before the era of vitamins, the value of yeast was recognized by animal husbandrymen who found they could get better performance by feeding the fresh yeast residue from breweries with their grains and mill feeds. Later, as the science of nutrition developed and specific nutritive values were discovered in yeast, the brewers processed their surplus yeast to a dried form so that year round, unperishable supplies of brewers' dried yeast were continuously available.

Yeasts used for brewing American beers are very small one-celled plants about the size of a human blood cell. They can be seen through a microscope as egg-shaped cells surrounded by an elastic membrane. When



Courtesy of Brewers Yeast Council, Chicago, Ill

FIG. 12.1. LIVING YEAST CELLS SECRETE ENZYMES THAT CONVERT GRAINS AND OTHER SUBSTANCES INTO MORE VALUABLE FEED PRODUCTS

grown under favorable conditions, this smallest of cultivated plants reproduces itself by a simple nonsexual method called budding every 20 to 30 min. Genetic control of yeast is practiced as in higher plants and pure-bred livestock.

Desirable yeast strains are propagated in large fermenters under sterile conditions which rival that of the most modern hospital. These strains are pure cultures as distinguished from the numerous mixed forms, good and bad, found in nature. All brewers' yeasts are of the species *Saccharomyces cerevisiae* which has certain unique properties as grown anaerobically under American brewing conditions. The liquid (wort) in which the yeast multiplies and ferments to produce beer is an aqueous extract of malted barley, rice, corn grits or flakes, flavored with hops.

Drying the surplus yeast residue over rotating drums heated internally by steam stops the life of the yeast, ruptures the cells, reduces the moisture content to about 5% and forms a product stable at room temperature. The yeast is dried in less than ½ min and at less than 212° F., and is then cooled and pulverized into a yellowish-orange, nonviable powder with a characteristic odor and flavor. Brewers' dried yeast contains no filler; it is 100% yeast solids.

Courtesy of Distillers Feed Research Council, Cincinnati, Ohio

FIG. 12.2 PURE CULTURES OF DESIRABLE STRAINS OF MICROORGANISMS ARE PROPAGATED TO SEED THE LARGE FERMENTERS IN PRODUCING FERMENTATION FEEDS

The Association of American Feed Control officials define brewers' dried yeast as the "dried, nonfermentative, nonextracted yeast resulting as a by-product from the brewing of beer and ale and shall contain not less than 40% crude protein." This distinguishes it from yeast cultures which contain live yeast cells in a considerable quantity of a cereal base upon which they have been grown. Live yeast cells may pass through the digestive tract without releasing their nutrients to the animal and may actually absorb thiamine from the intestinal contents. Yeast cells in brewers' dried yeast, on the other hand, are not alive and are in a form readily available to the animal.

In the brewing process, dried barley malt which contains a large amount of the enzyme, diastase, converts starches of the barley into the sugar maltose. High quality barley is steeped, sprouted, dried, and the sprouts separated. After malting, the mash is filtered. The residue is brewers' wet grains which are dried to a low moisture content to produce brewers'

TABLE 12.1

NUTRIENT VALUE OF BARLEY AS RECEIVED FROM FARM, AND FEEDSTUFFS RETURNED TO THE FARM

	Received from Farm				Returned to Farm					
	Barley				Spent Grains (Dry)		Yeast (Dry)			
	2400 Million Bu		Malt Sprouts 72 Million Lb		Compo-sition	70 Mill. Lb	Compo-sition	25 Mill. Lb	Total	
Total Quantity	%	Million Lb	%	Million Lb	%	Million Lb	%	Million Lb	Million Lb	% of Total
Protein	12.8	307	25.9	18	26.9	193	46	11.5	222	72
Carbohydrates	66.9	1605	46.9	33	41.4	297	37	9	339	21
Minerals	2.9	68	5.7	4	3.6	25	8	2	27	45
Fats	2.3	55	1.3	1	7.0	50	1	0.5	43.5	94
Fiber	5.5	132	12.4	9	14.3	103			95	84
Digestible prot.	10.2	243	19.7	14	21.8	157				
Total dig. nutr.	79.2	1902	74.4	53	66.4	476				

Brewers Yeast Council.

dried grains. The filtrate (wort) after treatment with hops is fermented with yeast which is recovered and dried to produce brewers' dried yeast.

Brewers' Dried Grains

Brewers' wet grains contain only 25% dry matter but otherwise are similar in composition to the dry grains. High moisture content makes them perishable; they become sour and moldy unless fed shortly after they are produced.

Brewers' dried grains may be stored for a long time because of their low moisture content. One pound contains the dry matter of 4 lb of the wet grains. Brewers' dried grains contain about 93% dry matter of which 65% is TDN which includes 21% digestible protein.

Only 1/10 as much malt sprouts are produced as brewers' dried grains. In many cases, they are blended with the grains. They absorb moisture readily and will mold if not stored properly.

Drying Brewery Products

A most valuable product of brewing is brewers' dried yeast. During fermentation, yeast reproduces itself at the rate of 4 to 1. Since only 1 lb is used again for "pitching" subsequent brews, there are 3 lbs of wet yeast (80 to 90% moisture) per barrel of beer that is recoverable for animal feeding. In certain localities, central drying plants handle the drying of the wet yeast from a number of breweries, both small and large. Feed manufacturers are assured of adequate supplies to meet their requirements throughout the year.

The first step in drying yeast is centrifugation to remove water. Next it is dried. A thin, uniform film of yeast slurry is spread on rotary drum driers consisting of steam heated stainless steel cylinders. Moisture is evaporated within a few seconds during a partial revolution of the drum. The dried film of yeast is removed from the drum with flexible scraper blades in the form of flakes and carried by a screw conveyor to a flaker with a fine screen or grinder.

Moisture between and in the yeast cells is evaporated during drying. This affects inactivation or destruction of the enzymes whose action would be undesirable in a dried product. Yeast is nearly sterile after drying. Brewers' dried yeast is marketed in powder and flake form, packaged in 100-lb moisture-proof multiwall paper bags.

To dry brewers' grains, the wet grains are passed over fine screens to remove the coarser grain particles and pressed to remove as much water as possible and yields brewers' wet grains with a moisture content of about 75%. The latter are then passed through rotary steam-heated tubular driers to bring their moisture content to an average of about 7%.

Nutrients of Brewers' Dried Yeast

Since the proteins of brewers' dried grains are derived chiefly from barley, and some rice and corn, they are deficient in some of the essential amino acids. Fortification of spent grains with yeast during the drying operation, if conducted in proper proportion, makes a superior feeding material. For *poultry feeding, only small quantities should be incorporated in the ration* because of their high fiber content.

Brewers' dried yeast from malted grain fermentation constitutes a natural concentrated mixture of essential nutrients. Biologically valuable proteins combined with high potency vitamin B-complex, important trace minerals, and several unique "plus" factors insure against deficiencies of known and still unrecognized nutrients. Brewers' dried yeast promotes vitality in the young, accelerates growth, and feed conversion. It has natural antioxidants to protect against peroxide formation, and possesses vitamin E-like activities, especially helpful in times of stress and during recovery from disease. Brewers' dried yeast is stable, free-flowing, available in various granulations and is a useful ingredient in poultry feeds, especially for turkeys and game birds.

Excessive body and liver fat develop in chickens maintained in cages for long periods of time. To prevent this, 10% brewers dried grains are added at the expense of corn, milo, and soybean meal. With this substitution, the gain in body weight and liver fat accumulation during 50 weeks is significantly less than with normal rations. Birds also grow faster, mature earlier, and produce greater numbers of eggs. These results suggest that brewers' dried grains contain an unknown factor or that the biological availability of recognized nutrients is greater.

TORULA YEAST

Dry yeast is produced from wood waste from the sulfite pulping process. Wood chips are cooked in bisulfite at temperatures from 266° to 302° F for 6 to 18 hr. During the digestion period lignin combines with sulfite to form soluble calcium lignosulfonate. After cooking is completed, the acid liquor containing the dissolved materials is separated.

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DISTILLERS' FEEDS

In the manufacture of distillers' feeds, whole grains ground to proper fineness, go to pressure cookers where they are made into a slurry with water and then cooked. After a cooling period barley malt is added which contains enzymes that convert starches into sugars. After further cooling, the material is pumped to fermentation vats, the pH adjusted with thin stillage, and the mash "set" with propagated yeast. The yeast carries out the fermentation and adds valuable vitamins to the recovered feeds.

The cereal grain mixture (corn, rye, barley, and malt) is referred to as the "mash bill" and the proportions of grain varies with the distiller and the type of whiskey being produced.

At completion of the alcoholic fermentation, the fermented slurry, called "beer" is run into a vat from whence it is pumped to the still tower where the alcohol and other volatile constituents are recovered as whiskey or beverage spirits. The remaining material, called "whole stillage" (containing 5 to 7% solids) is passed over screens (about 1 mm openings) to remove coarser grain particles. These screenings are pressed to remove as much water as possible and dried in rotary driers to produce light grains. These light grains constitute 50 to 55% of the total solids in the whole stillage.

Distillers' Solubles

The water-soluble materials and fine particles that pass through the screens are known as "thin stillage" which is evaporated under vacuum to a thick syrup containing about 30% solids. The syrup is drum or spray-dried and called dried distillers' solubles. Depending on markets, the syrup may be dried on the light grain in a rotary steam tube drier to produce dark grains or distillers' grains with solubles. This product can also be made by mixing distillers' light grains and dried distillers' solubles.

The grains which make up the "mash bill" alter the composition of the feed products secured. There are two extremes in mash bills; an "all-corn" mash bill which is composed of about 90% corn and 10% barley malt, and an "all rye" mash bill composed of about 85% rye and 15% rye malt. Special types of whiskeys may require all variations in mash bills between these two extremes.

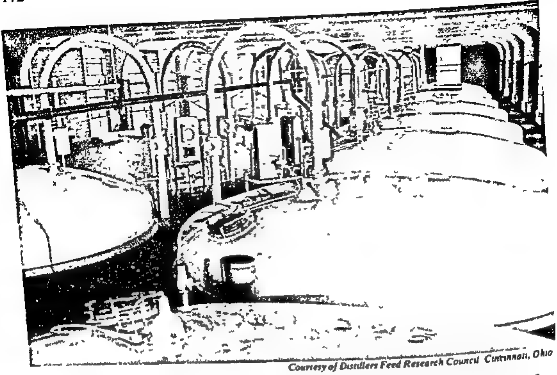
The mash bill affects the fat and protein content of all products. Rye yields lower fat but higher protein values in dark grains and in solubles. Rye light grains, however, contain only 18 to 26% protein depending on the mashing temperature. As far as chemical composition is concerned

TABLE 12.2

CHEMICAL COMPOSITION OF DISTILLERS' FEED FROM CORN, RYE AND A TYPICAL COMMERCIAL MASH BILL

%	Light Grains			Dark Grains (Grains with Solubles)			Solubles		
	Corn, 90% B. Malt 10%	Rye, 85% R. Malt 15%	Typical M.B.[1]	Corn, 90% B. Malt 10%	Rye, 85% R. Malt 15%	Typical M.B.[1]	Corn, 90% B. Malt 10%	Rye, 85% R. Malt 15%	Typical M.B.[1]
Moisture	11	11	11	11	11	11	5	5	5
Protein	30	18–26	28	28	29	28	25	36–38[3]	27
Fat	11	6	10	9	3	8	6	1	5
Fiber	11	15	12	7	8	7	1–3[2]	1–3[2]	1–3[2]
Ash	2	2	2	6	6	6	8–9	8–9	8–9
N.F.E.	35	44	37	29	43	40	52–55	44–49	51–54

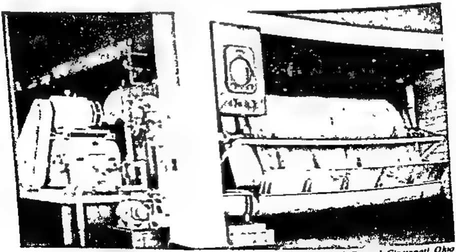
[1]Typical mash bill of 70% corn, 20% rye, and 10% barley malt.
[2]Lower (1.0%) fiber content in solubles produced by use of centrifuges
[3]Protein content of rye solubles decreases as mashing temperatures are increased



Courtesy of Distillers Feed Research Council Cincinnati, Ohio

FIG. 12.3. FERMENTERS IN DISTILLERY WHERE STARCHES ARE CONVERTED INTO SUGARS
After removal of the volatiles, the stillage is concentrated and dried to produce distillers' feeds with valuable protein and vitamins

the greatest difference between light grains, dark grains, and solubles is in the fiber and ash content. Light grains are much lower in vitamin content than dried solubles. Dark grains derive their vitamin potency from the solubles they contain.



Courtesy of Distillers Feed Research Council, Cincinnati Ohio

FIG. 12.4 SOLUBLE FERMENTATION FEEDS ARE CONDENSED AND DRIED ON DRUM DRIERS SO THEY ARE SUITABLE FOR INCORPORATION INTO POULTRY FEEDS

Distillers' dried solubles have much lower fiber but a higher ash and vitamin content than distillers light or dark grains. In addition, they contain factors as yet chemically unidentified of vitamin-like nature which increase growth rate and egg production of poultry. The evidence is that these factors are in much higher concentration in solubles than in light or dark grains.

The essential amino acid content of distillers' feed is also affected by the mash bill, although the differences are not as great as with vitamins. Microbiological findings on the amino acid content of distillers' dark grains and dried distillers' solubles from mash bills, predominately corn and rye, as well as a typical plant mash bill are shown in Table 12.3.

TABLE 12.3

PERCENTAGE AMINO ACID CONTENT (DRY BASIS) OF DISTILLERS' FEEDS FROM VARIOUS MASH BILLS

	Grains with Solubles			Solubles		
	Mash Bill			Mash Bill		
	Corn, 90% B. Malt 10%	Rye, 85% R. Malt 15%	Typical Plant[1]	Corn, 90% B. Malt 10%	Rye, 85% R. Malt 15%	Typical Plant[1]
Essential						
Arginine	0.9	1.2	1.0	0.6	1.4	0.9
Histidine	0.8	0.7	0.8	0.7	0.8	0.7
Isoleucine	2.0	1.6	1.9	1.5	2.0	0.7
Leucine	2.4	2.2	2.3	1.4	1.9	1.6
Methionine	0.5	0.4	0.5	0.4	0.5	0.4
Phenylalanine	2.1	1.4	1.9	1.7	1.8	1.7
Threonine	1.1	1.1	1.1	0.9	1.2	1.0
Tryptophan	0.1	0.3	0.2	0.1	0.2	0.1
Valine	1.8	1.7	1.8	1.4	2.1	1.6
Nonessential						
Serine	1.9	1.3	1.7	1.2	1.7	1.4
Tyrosine	0.7	0.5	0.6	0.6	0.6	0.6
Glutamic acid	5.7	5.5	5.6	4.3	...	...

[1]70% corn, 20% rye, and 10% barley malt.

Nutrients in Distillers' Solubles

Rye grains with solubles contain more arginine, lysine and, tryptophan than the comparable corn product. The threonine content of both corn and rye grains with solubles is the same. Corn grains with solubles are richer in the remaining essential amino acids. Rye solubles are somewhat richer than corn solubles in all essential amino acids other than lysine. Both solubles contain the same amount of lysine.

On a protein basis, distillers' feeds are deficient in the same essential amino acids as the grains from which they are derived, chiefly lysine, tryptophan, and methionine. However, the percentage of amino acids in the distillers' feeds are higher than the grains from which they are derived

because the protein is concentrated by the manufacturing process in which starch is removed.

The percentage of various mineral constituents in distillers' feeds which make up the ash content are presented from a typical plant mash bill composed of 70% corn, 20% rye, and 10% barley malt (Table 12.4). The solubles contain considerably more of the nutritionally important elements calcium, phosphorus, manganese, and magnesium than do either light grains or the original grains from which they are derived.

TABLE 12.4

PERCENTAGE MINERAL COMPOSITION OF THE ASH OF DISTILLERS' FEEDS (PLANT MASH BILL COMPOSED OF 70% CORN, 20% RYE AND 10% BARLEY MALT)

	Light Grains	Grains with Solubles	Solubles
Ash	2.0	6.0	8.0
Calcium	0.04	0.2	0.4
Phosphorus	0.21	0.8	1.6
Sodium	0.06	0.18	0.3
Potassium	0.09	0.8	1.8
Magnesium	0.06	0.3	0.8
Iron	0.01	0.03	0.05
Copper	0.007	0.007	0.008
Cobalt	0.00001	0.00001	0.00002
Manganese	0.002	0.006	0.01
Silicon	0.14	0.12	0.1
Sulfur	0.32	0.36	0.4
Chlorine	0.04	0.17	0.3

Recent interest in distillers' feeds in feeding poultry has leaned largely towards supplying unidentified growth factors (UGF). The additions of corn distillers' dried solubles to high energy, corn-soy-fat-fish meal rations improves growth and feed efficiency even when the rations are maintained isocaloric and isonitrogenous. Distillers' solubles rank well up in the list of high energy ingredients. Its protein content is approximately 3 times that of cereal grains and ½ as much as soybean meal. (Its methionine content is equivalent to that of soybean meal.) Thus, addition of corn distillers' dried solubles improves energy and protein values of the feed and also provides added amounts of methionine, the first limiting amino acid in practical diets for both broilers and layers.

Distillers' dried solubles are a good source of vegetable oils and linoleic acid. This is important because of recent evidence that vegetable fats have special properties which appear to be essential for maximum growth rate and maximum egg size, especially in young pullets. Distillers' dried

solubles are of value in helping nutritionists meet this linoleic acid requirement.

The production of distillers' feeds in recent years is given in Table 12.5.

TABLE 12.5

PRODUCTION OF DISTILLERS' FEEDS IN TONS 1945–67

Year Ending Sept. 30	Distillers' Dried Grains	Distillers' Dried Grains with Solubles	Distillers' Dried Solubles	Total
1945	352,600	195,400	85,500	633,500
1946	133,400	88,600	105,900	327,900
1947	157,400	148,700	105,200	411,300
1948	130,100	147,800	73,200	351,100
1949	86,900	188,200	57,800	332,900
1950	91,300	188,600	85,200	365,100
1951	199,700	288,600	145,600	633,900
1952	65,000	184,600	82,600	332,200
1953	40,000	116,200	29,500	185,700
1954	69,100	121,900	53,900	244,900
1955	66,300	130,900	53,000	250,200
1956	67,600	166,200	51,800	285,600
1957	59,100	185,300	45,900	290,300
1958	52,800	177,000	38,900	279,400
1959	43,800	251,400	53,200	348,400
1960	38,500	260,400	52,800	351,700
1961	28,400	264,700	59,500	352,600
1962	33,100	288,600	56,400	378,100
1963	25,200	312,900	24,100[1]	362,200
1964	24,000	339,600	18,100	381,700
1965	20,900	367,600	20,600	409,100
1966	27,300	379,000	21,400	427,700
1967	30,100	372,100	21,500	423,700

[1]Distillers' dried solubles only. Between 1956 and 1962, products containing extra solubles may have been included in tonnage figures.

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GREEN FEEDS

Green feeds are mainly sources of vitamin A activity, xanthophylls, and other pigments supplying color to the fat and egg yolk. Their protein is of good quality, and their trace minerals make a worthwhile contribution. Modern dehydrated green feeds are superior to those of the past due to inert gas storage, pelleting, and antioxidants.

Alfalfa

Alfalfa is known as a valuable feedstuff. It was grown in Iran in 500 B.C.; the Greeks and Romans were familiar with its value as a feed and soil improver and for its perennial nature, and methods of cultivation. "Alfalfa" in Arabic means "best fodder." "Lucerne," its European name, originated from the fact that it was cultivated for many years around Lake Lucerne in Switzerland. Gold seekers enroute to California by way of Cape Horn and South America brought alfalfa with them. A Chilean variety was introduced in California in 1850 and a German variety was introduced in Minnesota in 1857. In the United States, most alfalfa is grown in the Midwest and West. At first, a crop was harvested primarily as a sun-cured hay. Within recent years, the artificial drying of alfalfa "dehy" was developed into an important commercial industry. It produces a more uniform product with higher nutritional quality. The first dehydrator west of the Mississippi was installed in 1931. Most "dehy" is used in chicken rations but more is finding its way into turkey mashes.

Alfalfa breeding has been slanted toward greater yields, obtaining resistance to diseases, and selection of plants that have ability to produce more hay or seeds than others. Recently, there has been experimental work on propagating from individual clones. Buffalo alfalfa is purple-flowered, erect in its habits of growth, and quick to recover growth in the spring and after cutting. It is more resistant to leaf and stem diseases. Most of the nutrients in alfalfa are in the leaves. Therefore, any variety containing a high percentage of leaves is higher in nutritive elements than varieties that drop their leaves before being harvested. Buffalo alfalfa is grown successfully across the United States between the 31st and 43rd parallels; in the Southwest it competes with high-yielding, nonwilt-resistant strains.

Nutrients in Alfalfa.—Alfalfa is valued as nature's outstanding source of vitamins, minerals, and quality protein, plus still unknown factors which stimulate growth and reproduction, and improve the quality of all livestock. Dehy (meal or pellets) are practically dust-free and available throughout the year at prices highly competitive with other ingredients. It offers values as an ingredient in breeder rations which require moderate or low-energy feeds well fortified with protein, minerals, and vitamins. For

TABLE 12.6

AVERAGE XANTHOPHYLL CONTENT OF SOME NATURAL MATERIALS

Materials	Xanthophylls
	Mg per Kg
Marigold petal meal (*Tagetes erectaf*)	6000–10,000
Chlorella pyrenoidosa alga	4000
Common algae meal (*Spongiococcum excentricum*)	2200
Taiwan bee pollen	1325
Seaweed (*Fucus serratus*)	920
Dried stinging nettles (*Urtica*)	800
Broccoli leaf meal	670
Dried kao haole meal—Hawaii (called ipil-ipil in Philippines) (*Leucaena glauca* Linn)	660
Dehydrated clover meal	490
African red peppers, powdered	440
New York State pollen	440
Dehydrated alfalfa leaf meal (20% protein)	400–550
Seaweed (*Fucus vesiculosus*)	350
Mexico pollen	345
Seaweed (*Ascophyllus nodosum*)	340
Corn gluten meal (60% protein)	330
Spanish paprika	274
Ground annatto seed and hulls	265
Acidulated soybean soapstock	168–260
Dehydrated alfalfa meal (17% protein)	185–350
Coastal Bermuda grass	185–350
Dried chili peppers	185
Lakeweed meal	120
Corn gluten meal (41% protein)	90–180
Dried carrots	65
Dried sweet potatoes	55
Yellow corn	20–25

turkey breeder rations, it contributes important amounts of vitamin E and UGF. As little as 2% of dehy provides sufficient vitamin K for the chick. The pigmentation of broilers and egg yolks is an important economical factor to poultry producers and dehy is an important source. The use of grains with low xanthophyll content, and the lowering of dehy in the diet coupled with the emphasis on high energy diets have caused alarm relative to the lack of pigment in broilers.

TABLE 12.7

DEHYDRATED ALFALFA MEALS
COMPARATIVE NUTRIENT VALUES

	17% Protein	20% Protein	25% Protein
Proximate Analyses			
Crude protein, %, minimum	17.0	20.0	25.0
Fat (ether extract), %,			
Minimum	3.0	4.0	5.0
Crude fiber, %, maximum	25.0	22.0	17.0
Ash, %, maximum	10.0	10.0	10.0
Moisture, %	7.0	6.9	7.0
NFE, %	38.0	37.1	36.0
Energy (Poultry)			
Metabolizable, cal per lb	620	720	800

TABLE 12.8

RELATIONSHIP BETWEEN XANTHOPHYLL CONTENT OF DIET, β-CAROTENE-EQUIVALENTS, AND N.E.P.A. VALUES OF EGG YOLKS

Xanthophyll	β-Carotene Equivalents[1]	Approximate NEPA Number
Mg per kg Feed	(μgmβ-CE/Gm Yolk)	
0	. . .	. . .
15	25	1.0
25	30	1.3
35	45	2.5
45	60	3.3
55	75	4.4
65	85	5.0

[1]A.O.A.C. Method

Carotene Stability Problem.—The problem of carotene destruction during storage is being attacked in the U.S. by refrigeration and inert gas storage. These are helpful but are not used by smaller companies because of cost. Use of antioxidants is most promising at the present time. A most important constituent of dehydrated alfalfa from the standpoint of the feed mixer is protein. Alfalfa meal has hitherto been limited to 15, 17, or 20% protein grades. As stated, recent developments of separating leaf frac-

tions from the stem may make commonplace an alfalfa meal at 25% protein or higher. Dehy, in fact, is sold on the basis of its protein content. Common meal is guaranteed to contain 17% protein. Protein content of unblended meal depends upon the stage of maturity at which the alfalfa is dehydrated, weather and insect injuries. The amino acid and vitamin content of alfalfa are shown in table 12.9. It is seen that alfalfa meal contributes appreciable amounts of all the essential amino acids except methionine.

TABLE 12.9

AMINO ACID CONTENT OF ALFALFA MEAL

Protein Content	15%	17%	20%	22%
Amino Acids	%	%	%	%
Arginine	0.62	0.73	0.86	1.00
Lysine	0.63	0.76	0.89	1.04
Histidine	0.32	0.36	0.40	0.48
Methionine	0.21	0.24	0.31	0.35
Cystine	0.20	0.20	0.20	0.20
Methionine and cystine	0.41	0.44	0.51	0.55
Tryptophan	0.39	0.44	0.46	0.55
Glycine	0.71	0.86	1.00	1.13
Phenylalanine	0.78	0.83	1.06	1.16
Tyrosine	0.42	0.50	0.68	0.75
Phenylalanine and tyrosine	1.20	1.33	1.74	1.91
Leucine	1.07	1.27	1.50	1.70
Isoleucine	0.60	0.72	0.82	0.94
Threonine	0.63	0.76	0.87	0.97
Valine	0.74	0.92	1.01	1.16
Aspartic acid	1.72	1.87	2.09	2.30
Glutamic acid	1.48	1.72	2.06	2.28
Proline	0.80	0.89	1.02	1.12
Serine	0.66	0.74	0.85	0.90
Alanine	0.80	0.91	1.13	1.27

From: American Dehydrators Assoc.

The alpha tocopherol content of dehydrated alfalfa meal varies widely. In one series, the content ranged from 2.8 to 14.1 mg per 100 gm due to the stage of growth at cutting, elapsed time between cutting and dehydration, storage time and conditions, and many other factors. It is impractical to quantitate the contribution of biologically available vitamin E activity from the various tocopherol values in a feedstuff or ration. There might be incomplete assimilation of certain tocopherols from the ration. There may also be a three- to fourfold difference between the high and low values of standard ingredients.

The amount of carotene present at the time of dehydration varies considerably with the season and stage of maturity at which the crop is harvested. If harvested in early bloom, it contains 150,000 to 250,000 IU of vitamin A potency per pound; it decreases rapidly if harvest is delayed

TABLE 12.10

VITAMIN CONTENT OF ALFALFA MEAL

Protein % Grade	15%		17%		20%		22%	
Vitamins	ppm	mg per lb	ppm	mg per lb	ppm	mg per lb	ppm	mg per lb
Beta carotene	102.1	46.4	161.2	72.95	216.4	98.2	252.5	114.59
Xanthophylls	175.0	79.7	257.0	116.9	328.0	149.0	401.0	182.0
Thiamine	3 0	1.37	3.5	1.5	3.9	1.76	4.2	1.91
Riboflavin	10.61	4.81	12.31	5.59	15.50	7.04	17.4	7.9
Pantothenic acid	20.91	9.49	30 0	13.61	32.8	14.9	33.0	14.99
Niacin	41.90	19.02	45.82	20.8	54.7	24.83	58.8	26.68
Pyridoxine	6.50	2.93	6.3	2.86	7.9	3.6	7.8	3.52
Choline	1550	703.7	1518	689.2	1618	734.6	1853	841.3
Betaine	4670	2110	4806	2180	5598	2540	5434	2465
Folic acid	1.54	0.70	2.1	0.95	2.67	1.21	3.0	1.36
Vitamin K	9.9	4.48	8.7	3.95	14.7	6.66	8.5	3.86
Alpha tocopherol	98.0	44.5	128.0	58.1	147.0	66.73	151.0	68.55

From: American Dehydrators Assoc

until the crop is past early bloom. It is customary for the seller to guarantee carotene per pound. Other pigments in alfalfa are chlorophyll and xanthophyll, but these are not of importance as yet. Chlorophyll is present in excess of 3,000 ppm, and xanthophyll 400 ppm. Most of the known vitamins are found in alfalfa.

Growing of Alfalfa.—Alfalfa is a multiple crop. The important factors in maintaining a stand are to keep plants healthy and vigorous, and to allow the plant time between cuttings to accumulate food in the roots to make more vigorous growth. The critical period is in the fall season and it is necessary to plan the late cuttings in order to allow the fall top growth to supply the roots with plant foods for winter protection. The best management practice is to make the 2nd cuttings in the early stages of growth and make the 3rd and 4th after sufficient top growth is developed. In this way, the plant can build up food reserve in the roots for winter protection after the last cutting.

Carotene content in alfalfa is controlled by factors which rest on complex interactions between environment and heritable factors within the plant. Young alfalfa is higher in vitamin A potency than alfalfa in the bloom stage. Potency is continually being built up until the bloom period of the plant. Commercial practices cut alfalfa in the early stages of growth to assure a high quality product because of the high percentage of leaves. Recommended practice is to cut in the 10th bloom stage.

Production of Dehydrated Alfalfa. –Dehydrated alfalfa is of much higher quality than sun-cured alfalfa. Alfalfa is dried rapidly by artificial means at a temperature above 212°F. Dehydrators are high temperature units of rotating drum-type construction, usually 10 to 12 ft in diameter and 20 to 30 ft long. Gas is the usual fuel but oil and coal have been used. In

order to produce good quality dehy, it is necessary to have good quality raw material.

Alfalfa can be damaged by poor handling and dehydration. It is dried as soon after cutting as possible, since destruction of nutrients in the alfalfa, particularly carotene, begins as soon as the alfalfa is cut. The length of time between cutting the alfalfa and feeding it into the dehydrator is less than 1 hr. Special pieces of equipment used in processing are blending equipment, pelleting machine, automatic weighing and sacking equipment, loading devices, coolers for cooling meal before sacking, spray equipment for adding oil to the dehydrated alfalfa, shredders for disintegrating the stems before dehydration, and numerous other items.

Pelleting makes it possible to handle dehy with bulk equipment and reduce labor costs. Cost of bags amounts to $8.00 per ton. Dehy has been separated into fibrous stemmy parts and a finer leaf fraction richer in both protein and carotene. The smaller bulk of the latter permits it to be stored under refrigeration or in inert atmosphere at less cost than the total meal; 80% of the carotene can be concentrated into a fraction containing 65% of the weight. A high quality meal containing 200,000 IU per lb is separated into 2 fractions: a large fraction which has a carotene content of 246,000 IU per lb and contains 65% of the meal, and a smaller fraction with 114,000 IU carotene per lb and contains 35% of the meal. The latter fraction is still a good meal and meets the maximum specifications for a guaranteed carotene content of 100,000 IU.

Although artificial drying has been practiced for many years, the commercial application of the principle of pneumatic drying dates back only to 1930. Fundamental factors that govern rate of moisture removal are:

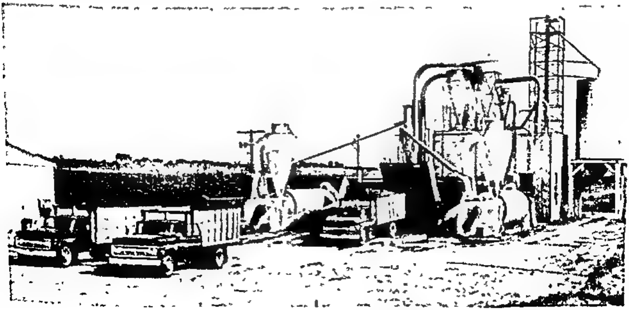

Fig. 12.5. A Typical Alfalfa Dehydrating Plant in Operation

moisture distribution, temperature differential, agitation, and particle size. Material having the shape of a flake is ideal to dry to low moisture values in a pneumatic-type dryer because of the short distance for moisture migration. Dehydrated alfalfa is stored before being marketed since production is limited to about six months of the year. High quality meals are produced early in the season and used for blending operations later. Peak use occurs during the winter.

Some alfalfa meal is pelleted after passing through the hammer mill. The most common size is 3/16-in. in diameter. Dust problem is not as troublesome as pellets can be handled with grain weighing and loading equipment for bulk shipment. Pelleting requires careful control of moisture if the pellets are to be satisfactory. Pelleting has certain advantages: it increases xanthophyll availability and metabolizable energy, the dust problem is diminished, less volume is required for storage, and bulk loading is quite satisfactory. Sometimes a binder such as bentonite is used in quantities of less than 2%. Alfalfa is dried to a moisture content of 6–8% on a dry weight basis. Dehy picks up as much as 2 to 4% moisture from the atmosphere. The dust hazard in storage is eliminated in part by the use of a small amount of oil added to the meal. Oil has no stabilizing effect on the carotene in alfalfa.

Freshly dehydrated alfalfa has a greater content of carotene than alfalfa which has been sun-dried. Properly dehydrated alfalfa contains 95% of the carotene present in the fresh alfalfa; sun-cured alfalfa contains 20 to 50% of the original carotene. Both meals lose vitamin A potency during storage because of slow oxidation. Most dehydrating companies use an antioxidant, pellet the product, and store it under gas. Since carotene destruction is an oxidative process, carotene loss is reduced if the oxygen surrounding the particles is replaced by a nonoxidizing atmosphere. The process consists essentially of placing the meal in large steel bins and flushing out the air with gas produced by the incomplete burning of natural gas or by nitrogen.

The vitamin A requirement of poultry is supplied from several sources. The carotenoids from plant sources are an economical form. Carotenoids are yellow, fat-soluble pigments produced by growing plants. Several carotenoids possess vitamin A activity, including lycopene, cryptoxanthin, and the carotenes. There are three forms of carotene, alpha, beta, and gamma. Beta is the most common and biologically active form and is found in yellow carrots, sweet potatoes, green grasses, and forages.

Destruction of carotene is very rapid after freshly cut plants begin to wilt so it is dehydrated as soon as it is possible. The loss of carotene during wilting and drying is caused by light and enzymatic oxidation. Dehy loses 50-60% carotene in 3 to 6 months under ordinary storage conditions due to light, enzymes, heat, and oxygen.

TABLE 12.11

VITAMIN A ACTIVITY PER LB OF DEHY FOR SEVERAL SPECIES OF ANIMALS

Species	Conversion-Mg of Beta Carotene to I. U. Vitamin A	Protein % Grade 15%	17%	20%	22%
Standard (poultry and laboratory rats)	1 = 1,667	77,349	121,608	163,699	191,022
Beef cattle	1 = 400	18,560	29,180	39,280	45,836
Dairy cattle	1 = 400	18,560	29,180	39,280	45,836
Sheep	1 = 400–600	18,560 to 27,840	29,180 to 43,770	39,280 to 58,920	45,836 to 68,754
Swine	1 = 500	23,200	36,475	49,100	57,295
Horses					
growth	1 = 555	25,752	40,487	54,501	63,597
pregnancy	1 = 333	15,451	24,292	32,701	38,158
Dogs	1 = 833	38,651	60,767	81,801	95,453

From: American Dehydrators Assoc.

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TABLE 12.12

LOSS OF CAROTENE FROM ALFALFA MEAL AT VARIOUS TEMPERATURES

Storage Temperature °F	Length of Time, Days	% Loss of Carotene
−9 to −15°	180	10
14 to −5°	180	14
34 to 43°	180	50
98°	16	38
140°	16	66
176°	16	98

Alfalfa meal also contains a considerable quantity of minerals essential to good nutrition. Alfalfa is usually fed at levels of 2 to 5% of the poultry rations. Higher levels of dehy in mixed feeds decreases weight gains slightly which is not due to fiber content entirely. Alfalfa contains saponin which has physiological effects on poultry and limits the amount that can be placed in the ration. Toxic substances in alfalfa can be eliminated by exhaustive extraction of the meal with hot water. The extracted meal has little growth-depressing activity while the water extract produces marked inhibition of growth. The inhibitor has hemolytic properties; possibly it is a saponin.

TABLE 12.13

MINERAL CONTENT OF ALFALFA MEAL

Protein % Grade	15%	17%	20%	22%
Macrominerals (%)				
Calcium	1.23	1.30	1.47	1.47
Phosphorus	0.22	0.23	0.27	0.28
Potassium	2.30	2.40	2.50	2.50
Sodium	0.07	0.08	0.08	0.10
Chloride	0.45	0.47	0.57	0.53
Magnesium	0.26	0.26	0.32	0.32
Sulfur	0.17	0.22	0.43	0.30
Microminerals (PPM)				
Manganese	27.0	28.0	34.0	39.0
Iodine	0.12	0.15	0.14	0.20
Iron	230.0	309.0	281.0	306.0
Copper	8.6	8.2	8.6	9.0
Zinc	19.0	17.0	19.0	21.0
Aluminum	226.0	314.0	267.0	295.0
Barium	42.0	37.0	32.0	38.0
Strontium	75.0	71.0	90.0	95.0
Boron	38.0	44.0	47.0	49.0
Chromium	2.0	2.3	3.0	3.0
Selenium	0.50	0.60	0.50	0.54

From: American Dehydrators Assoc.

Dehy is used also in turkey rations. A coarsely ground material is preferred to fine ground meal used for chickens. Up to 20% of alfalfa is desired for finishing rations from 16 to 28 weeks and for breeding operations.

Broiler raisers are vitally concerned with pigmentation of birds which is due to the xanthophyll content of the feed. Twenty percent protein dehy contains nearly 80% more productive energy than the 17% grade. Dehy is of higher quality now than ever before and provides one of the most economical sources of nutrients.

OTHER DEHYDRATED GREENS

Important cultivated grasses in the United States are timothy, Kentucky blue grass, Red Top, Bermuda grass, orchard grass, carpet grass, Canada blue grass, tall meadow grass, meadow fescue, foxtail millet, Rhodes grass, Napier grass, sheep fescue, red fescue, Para grass, Japanese millet, Italian rye grass, perennial rye grass, colonial bent, Dallas grass, and Sudan grass. A good yield of high-protein, low-fiber, high-carotene feeds can also be obtained from a grass and clover mixture which is preserved by artificial drying followed by storage in bales. Other green feeds include: Kudzu, a perennial legume that produces large yields of hay in the South; Ramie meal, the tops from one of the truly ancient fiber sources grown in the Florida Everglades; dehydrated lettuce meal from California, the dried lettuce waste composed of the outside leaves and poorly formed heads obtained as a by-product of the table market crop; and dehydrated celery tops, the waste from the vegetable growing operation.

Vegetable Wastes

Vegetable wastes occur at the farm, packing shed and processing plant and consist essentially of discarded wastes including, vines, leaves, tops, roots, trimmings or peelings, as well as crops that are not harvested because of unsatisfactory quality, market conditions, and shortages of labor. Because of their highly perishable nature and rapid accumulation, they must be disposed of as quickly as possible. The leaves of the plants are by far the richest constituents and these can be used in animal feeds as a source of carotene, protein, and minerals. From the standpoint of abundance, occurrence in large concentration and nutritional value, the leafy waste of the following vegetables have the greatest promise: beets, broccoli, cabbage, carrots, cauliflower, kale, rutabagas, turnips, spinach, and tomatoes.[1] Leaves are about twice as nutritious as the stems. Broccoli leaves are particularly high in all nutrients. Other waste products used in poultry feeds are winery wastes, asparagus wastes, pineapple by-products, and cull apples.

[1]Tomatoes do not have a utilizable leafy waste but there is an abundance of processing plant waste commercially used in feeds.

TABLE 12.14

PROTEIN, CRUDE FIBER, FAT, CAROTENE AND RIBOFLAVIN IN VEGETABLE WASTES

	% Protein			% Fiber			% Fat	Carotene (Mcg per Gm)			Riboflavin (Mcg per Gm)		
	Leaves	Stems	Unseparated Leaves and Stems	Leaves	Stems	Unseparated Leaves and Stems	Leaves	Leaves	Stems	Unseparated Leaves and Stems	Leaves	Stems	Unseparated Leaves and Stems
Beet	31.9	17.0	. . .	5.8	12.9	. . .	6.2	460	36.7	. . .	16.6	5.9	. . .
Broccoli	32.8	. . .	. . .	10.5	. . .	. . .	6.1	670	. . .	. . .	22.9	. . .	12.4
Cabbage, Savoy	22.4	. . .	. . .	8.2	. . .	. . .	4.7	295	. . .	. . .	9.9	. . .	. . .
Carrot	18.0	9.8	14.4	9.1	16.9	12.4	4.0	274	122.0	240	9.1	5.8	8.3
Cauliflower	26.6	17.1	. . .	9.5	17.28	. . .	4.1	185	28.0	. . .	23.2	9.2	. . .
Collard	27.3	14.8	19.2	6.8	9.8	8.5	5.3	251	28.8	115	15.8	. . .	9.4
Corn, sweet	17.1	. . .	. . .	26.6	. . .	. . .	5.5	578	. . .	. . .	5.5	. . .	. . .
Kale	27.1	15.7	21.5	7.3	10.5	8.6	6.3	266	24.8	196	16.0	8.2	12.0
Lima bean	17.6	12.3	. . .	9.6	27.5	. . .	4.1	176	. . .	. . .	10.7	. . .	. . .
Parsnip	22.9	6.0	. . .	8.0	17.2	. . .	5.0	232	4.3	. . .	11.9	4.3	. . .
Rutabaga	31.5	18.5	. . .	6.3	14.9	. . .	6.5	257	13.4	. . .	20.9	8.5	. . .
Turnip	30.4	18.0	22.5	7.8	10.3	8.3	4.4	264	54.0	176	14.7	11.6	. . .
Spinach	32.0	22.5	30.4	6.8	9.3	6.3	4.1	314	120.0	272	14.6	8.5	13.3

Inasmuch as vegetable crops are frequently treated with insecticides that contain toxic materials, such as lead arsenate or copper compounds, their residues must be within safe limits in the final product. Artificial drying of immature pasture herbage is done in a two-tray batch dryer followed by baling to give a product which retains its original green color.

Pasturage

If all variables such as disease and parasites could be eliminated and only nutritional factors considered, range-reared replacement stock would consistently lay at a higher rate with a lower percent mortality than confinement-reared stock. The nutritive values obtained from the range is directly obtained from herbage consumed, from the soil, bugs, and worms, and from irradiation by the sun. Palatable green herbage contains an abundant supply of such essentials as carotene, riboflavin, vitamin K, pyridoxine, pantothenic acid, niacin, biotin, choline, and others.

Today, poultry raising is a year-round industry and a large proportion of meat birds such as commercial broilers and laying birds are now grown indoors to market age. Large commercial poultry enterprises require fast growth, high rate of egg production and efficient feed utilization and these conditions are best met by high-energy rations. Forage does not fit into this picture. As has been pointed out, the digestive tract of the chicken is not adapted to the utilization of fibrous feeds. Legumes such as Korean *Lespedeza*, ladino clover, crimson clover, and Sudan grass have proven especially valuable because they supply excellent grazing during the hot, dry summer months when grasses are usually dormant. *Lespedeza* reseeds itself even when grazed short and once established there is no need for reseeding.

Turkeys are by nature better adapted to grazing than chickens. They make the largest use of forage when the concentrate is fed in limited amounts. Turkeys reared on green forages are healthy and heavy, more

TABLE 12.15

ESTIMATED YIELDS OF DRIED VEGETABLE WASTES

Raw Material	Yields, % of Raw Material: Leaves	Leaves and Stems
Beet tops	6–8	12–15
Broccoli-leaf waste	7–8	13–16
Carrot tops	11–12	20
Kale	10	18
Lima bean leaf fraction (from vine apron)	23	28
Pea vines (from vines)	. . .	15–19
Turnip tops	6–8	15–17
Spinach	8	12

From. U.S. Dept. Agr. Eastern Reg. Res. Lab. Philadelphia

so than those reared in confinement or under range conditions where good forage is limited. Poultry on good pasturage need only simple, comparatively inexpensive mash, and whole grain. This is of particular interest to farmers who grow relatively few birds but have plenty of grass, clover, weeds, and insects available.

Good pasturage for chickens involves a number of factors, such as succulent green feeds, isolation, and ample space. It is necessary to mow often during the late spring and summer to encourage continued growth and succulence of the grass, weeds, and clover. A good range provides insects which make a valuable supplement for the green feeds. The range for chicks and growing pullets should be isolated from older birds carrying diseases and parasites. Attempts to raise chickens and grow pullets on a range frequented or recently contaminated by older chickens is a most frequent cause for the failure of the farm poultry raiser to grow first class pullets which will live and lay. A well isolated, clean range with plenty of herbage is the keystone to successful and economical poultry raising on pasture.

Fresh, immature grass is the finest kind of supplementary feed that can be produced, being particularly high in many of the essential vitamins and minerals. The same grass at a later stage is less valuable, and in case it is dry and stringy, may be positively detrimental. When grass is mowed frequently, the stubble is short, stiff, and stands up straight. Droppings from the birds work down in this stubble and are soon lost sight of. Mowing keeps young grass coming up and the result is a fresh, high-potency immature grass for the birds to eat. Frequent clipping of the immature grasses increases the acreage yields of protein 40 to 60% over that recovered by the usual haymaking procedure.

Alfalfa is grown for pasturage quite generally in the United States except where the soil is too acid which requires tremendous applications of lime and very careful innoculation of the seed in order to get a good stand. Alfalfa has some bad features. The crop grows well and a dense growth is obtained which allows little or no penetration of the sunlight to the soil. Chickens flatten down the alfalfa and droppings accumulate on this matted mass so that the birds are in contact with contamination at all times. Very much the same conditions occur where clover is used. Ladino makes a taller and ranker growth than ordinary white clover and is excellent for pasturage.

UNUSUAL FEEDS

Noncereal carbohydrate feedstuffs such as yucca, manoic, and cassava are used in some countries in poultry rations to replace grains up to 20%. A disadvantage is the necessity for some kind of processing. Shrimp meal can replace equal quantities of fishmeal and is a very valuable feed if

economics are in its favor. The lobster industry yields nearly three tons of offal for every ton of tail. It is processed into a valuable meal containing 28% protein and is high in minerals. Silkworm pupae is also a source of animal protein for poultry feeding replacing equal amounts of fishmeal. Groundnut (peanut meal) gives satisfactory results especially if its deficiency in methionine, lysine, and minerals are balanced by other ingredients of the ration and if the product is free of aflatoxins.

Coconut meal can be added to poultry rations up to 15 to 20% of the total if lysine and energy contents of the total ration are well-balanced. Solvent extracted meals are superior to those extracted by older processes. Linseed oil meal has a growth retarding and laxative effect when fed to poultry, so should be kept at levels of not more than 3 to 5%. Substantial amounts of hevea seed cake meal are produced on rubber plantations. This meal has a composition similar to linseed oil meal, but contains variable amounts of glucoside from which prussic acid (HCN) is split. This agent can be removed by washing and drying the finely ground cake.

Kelp

A machine has been developed to harvest and dry water milfoil and other dense growth from clogged bays or lakes. Aquatic weeds provide compost and mulch for commercial gardeners and can be used in feeds. The machine's principle is a cutting bar which can be set at varying depths. The cut plants are carried over a series of rollers to press out excess water of the weeds which have been moved to a hydraulic lift on the rear of the machine. The entire unit is a self-propelled barge loaded with machinery.

Triticale

Triticale, a wheat-rye hybrid, with promising agronomic characteristics has a higher protein content than that of either parent. Preliminary tests indicate its nutritional value for feeding chicks is below that of wheat and corn when used as the only grain.

Guar

Guar is an annual, summer, row crop best suited for cultivation in the Southwest. It is grown on acreage diverted from feed grains. It is a nitrogen-fixing legume like alfalfa, but its seeds yield a vegetable gum when processed. The gum is used in foods and for other purposes. *Plantago obata* is best adapted to the Southwest.

Cramba

Cramba seed is a source of erucic acid, useful as a drying agent and an ingredient of hydraulic fluids. It is adaptable as a spring crop in the Midwest and Pacific Northwest wheat areas and as a crop in Texas.

Kenaf

Kenaf is a single-stock fibrous plant currently grown in Florida as a source of paper pulp. The top 36 in. of the plant is dehydrated, ground and used for its pigment. Kenaf contains less xanthophyll than alfalfa but if it could be harvested from less mature plants or if only the leaves could be used, this source of xanthophyll would be satisfactory to color broilers and egg yolks. Kenaf is as effective as alfalfa when both are used at equivalent xanthophyll levels.

Hevea Seed Cake Meal

Dehulled hevea seed cake meal can be included in poultry rations up to 5%. In the Far East, mung beans replace 20 to 40% of the animal protein in balanced poultry rations. Although other legume seeds could be incorporated in poultry rations, some are toxic even in small quantities and others, like bitter lupine, are unsuitable because they impart a bitter taste to the eggs. The toxic factor or growth inhibitor can be removed by washing and drying the ground seeds as in the Philippines with ipil-ipil seed meal.

Kashz

A dry fermented sheep's milk product, "Kashz" is used in poultry feeding in the Middle East as a replacement for fishmeal. It is very high in protein and fat.

Potatoes

Cull potatoes may be cooked with a little salt and fed to poultry. One gallon of cooked potatoes is equivalent to a quart of grain. They contain 23% as much dry matter as shelled corn. The dry matter is mainly carbohydrate.

Bakery Products

Stale bread and other bakery products are high in carbohydrate and have a composition similar to grains. Bakery products may be used to replace a part of the grains fed to poultry and considered as energy substitutes. They have about ¾ the value of grain.

Buckwheat

Buckwheat is unpalatable because of its dark, unattractive appearance and high fiber content. Ground buckwheat or buckwheat middlings may be used to replace 10 to 20% of other grains or their by-products in poultry mash feeds.

Linseed Oil Meal

Linseed oil meal is made from flaxseed and is not as palatable as soybean meal or corn gluten meal.

Peanut Meal

Peanut meal is a good vegetable protein supplement and may be used economically in poultry rations where available. However, the quantity produced in the United States is small and it is used mostly in only a few southern states.

Charcoal

Charcoal has very little more value than sawdust and there is no conclusive experimental evidence for justifying its use in poultry feeds. It can adsorb some nutrients and make them unavailable to birds because charcoal is not absorbed.

Tonics

Tonics are supposed to stimulate appetite and increase feed consumption. Their value has not been proved by careful experimentation.

Algae

Algae have been used in livestock and poultry feeds. Grown on organic wastes at low cost, conversion efficiency is high. The ultimate cost of animal protein so produced is several-fold less that of feeding conventional crops for animals. Waste material can be human sewage as well as organic industrial waste and livestock manure. The cost of algae culture can be minimized by growing the algae in open outdoor ponds. Nutrients for the algae are provided through the aerobic decomposition by bacteria of the organic matter in the sewage. *Chlorella* and *Scendesmus* are the two most abundant types encountered.

Harvesting of the algae crop involves three steps: initial concentration, dewatering, and drying. The initial step yields a slurry having a solids content equal to 1 to 2% of the net weight. Dewatering results in a paste having a solids content ranging from 8 to 15% of the net weight. After dehydrating or drying, the moisture content of the algae product is reduced to 8 to 12%. Extensive studies are required before complete evaluation can be made of the algae products as poultry feedstuffs.

Activated Sludge

Activated sludge has been dried as an adjuvant to poultry feeds. Activated sludge is a by-product of treated sewage sold frequently as an organic fertilizer. It has been found to contain extensive vitamin B-complex vita-

mins, especially vitamin B_{12}, many important amino acids, and several unknown growth factors. Meat of animals produced from the sludge is satisfactory.

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Energy

INTRODUCTION

There is no *ONE* most important nutrient, unless it is the one that is *MISSING!* All nutrients are equally important to the extent they are needed in a particular formula. If any essential one is inadequate in amount, it is the critical nutrient for that ration.

The traditional method of evaluating the nutritive value of a feed is to express its composition in terms of nutrients, i.e., water, carbohydrates, fats, protein, minerals, and vitamins. With the exception of water, each of the above nutrients consist of not one but a number of substances, each having distinct nutritive value. For example, vitamins A and B_{12} are widely divergent substances, both chemically and physiologically, yet the term "vitamin" is used to designate both. Although not nutrients, such additives as antibiotics, arsenic acid derivatives, sulfa drugs, and surfactants are groups of substances and appear to play an important role in nutrition. All are used in practical feeding and will be later considered in detail and an attempt will be made to interrelate them.

Natural feeds vary widely in the kinds and amounts of nutrients which they contain. In addition, unidentified growth factors are in liver, yeast, fishmeal, distillers' dried solubles, dried whey, grass juice, and alfalfa meal. Many members of the vitamin B-complex are available in pure crystalline form or have been synthesized. Dietary needs for the various vitamins vary widely among species. Growing chicks are unable to synthesize some of the nutrients sufficiently to permit rapid growth and consequently must be included in the diet.

B-complex vitamins when supplied in excess of normal requirements are not toxic or harmful. They are not stored in the tissues of organisms, thus a continuous supply is desirable. A carryover of certain vitamins through the egg to the chick plays an important role in hatchability and survival of the chicks during early stages of growth.

In formulating poultry rations, consideration must be given to the following nutrients in addition to water: a source of nitrogen-free extract and fiber; 1 to 3 essential fatty acids; 12 essential amino acids; a nitrogen source for the synthesis of nonessential amino acids; 13 minerals, including 8 major and 5 minor; 4 fat-soluble vitamins; 12 B-complex vitamins; 2 unidentified vitamins, and antibiotics or other growth stimulants. Over 50 entities have thus to be taken into consideration in compounding practical rations. Poultry feeds have changed greatly during the past few dec-

ades. They are no longer simple mixtures of a few ingredients as they were at one time.

The assumption that all the nitrogen present in feedstuffs is in the form of protein is not true, since other nitrogenous compounds such as nitrate, nitrite, purine, choline, and free amino acids are also present. Gross energy of feeds, determined directly by burning a sample, results in good agreement with those obtained by calculation. Organic acids such as malic, citric, ascorbic, oxalic, lactic, succinic, acetic, and malonic, are distributed widely in feeds but for the most part in small concentrations. In some feeds the acids are sufficiently abundant that they are determined separately for estimations of energy values, since their heat of combustion is lower than for carbohydrates. The heat of combustion for fat-free muscle meat is 5.65 cal, for the nitrogenous portion of egg 5.75 Cal per gm. In fermentation products, the total acidity of the product may be increased severalfold over the original content. Many items of animal origin contain small amounts of carbohydrates. Fats of plant origin are more important today than a number of years ago. General factors of 4 Cal for protein, 9 Cal for fat, and 4 Cal for carbohydrate provide a quick means of calculating the physiological fuel value from composition data of the total feed supply. These factors are used for estimating values of average diets from the total quantity of protein, fat, and carbohydrate. More specific factors should be used for experimental rations, individual foods, and food supplies of a totally different character and for areas of the world where the food supplies consist largely of unrefined feedstuffs.

THE RELATIONSHIP OF ENERGY AND FOOD COMPOSITION

Recent investigations show the importance of relationships of energy to various nutrients. Scott *et al.* (1947) demonstrated that high energy diets permitted broilers to grow more rapidly and utilize their feed more efficiently. Later, Cornell investigators found that the protein requirement for maximum growth appears to be a relatively constant absolute quantity, but as a percentage of the ration, was related to productive energy level through its influence on feed intake. Feed intake of poultry is, in turn, determined largely by energy concentration providing the diet is adequate and bulkiness does not limit intake. Since protein and energy are the most expensive nutrients in a practical ration, their efficient use is critical for economical production of meat and eggs. Consequently, it is desirable to relate the level of protein (amino acids) to the energy level of the ration. In order to satisfy energy requirements when moderate amounts of cellulose replace glucose, birds consume more feed. This means more protein is available for growth. At high levels of cellulose, the volume of food consumed is high, but growth rate is limited by an energy

deficiency caused by the low energy level of the diet. The calorie-protein (C/P) ratio is defined as the productive energy (k-cal.) per pound divided by the percentage of crude protein in the ration. Best results are obtained with a broiler starter ration having a C/P ratio of 41 and a finisher ration with a C/P ratio of 49. Poor feathering occurs in birds receiving a calorie-protein ratio of 54.

There is a linear relationship between energy value and efficiency of egg production in Leghorns. The beneficial effect obtained from fat supplementation can be attributed to increased density and improved palatability. If the ration is pelleted, supplementary fat does not increase growth rate. Body composition is influenced by altering the C/P ratio, primarily due to its effect on appetite. Laying hens fed low-protein diets overconsume on feed energy while withdrawing body protein in order to sustain good egg production.

There are interrelationships of energy with other nutrients. The level and also the type of dietary fat has an influence on calcium utilization by the chick as measured by growth rate and tibia bone ash. Although there is some controversy concerning this effect, the greatest divergence of opinion occurs when extremely high impractical fat levels and extremely low calcium are employed. With addition of fats, the requirements of chicks for choline, riboflavin, folic acid, and methionine are increased. When sufficient energy is available, the methionine requirement expressed as percent of the diet increases as the protein level increases. The best correlation between growth performance and calculated requirement is obtained when requirement is considered as a function of the calorie-protein ratio. Maryland workers found increased requirement of sulfur amino acids in growing chickens on high energy rations. They point out that the methionine requirement varies with energy level because when rations contain more energy, birds simply eat less. Therefore, the intake of methionine is less. The requirement for methionine can be expected to vary considerably when expressed as percent of the ration with different size of birds, season of the year, production level, egg size, and energy content of the feed. A similar set of relationships holds for the lysine requirement. The proportion of energy to protein content appears to fix amino acid requirements for broilers. If the requirement for energy is the primary factor controlling feed intake, the need for other essential nutrients is related directly to the energy content of the ration.

Fraps of Texas showed that feed ingredients with higher fiber content contained less energy than feedstuffs with lower fiber composition. The amount of nutrients a chicken consumes per day depends on the density of the diet rather than on its total weight. The weight of feed required to produce a pound of gain, therefore, does not give a true picture of the

amount of nutrients consumed by chickens on high-fiber diets. Decreasing the caloric content of a 16% protein breeder diet reduces hatchability. The chief limiting effect of fibrous materials for both gain and feed efficiency is their effect upon calorie-protein ratio. Reports on the level of energy to specific vitamins are rather limited. Studies with turkey poults showed that the riboflavin requirement is more highly correlated with the energy content of the diet or to the daily intake of riboflavin than to the amount of riboflavin per pound of feed. Increasing the energy content of the chick diet also increases the need for potassium. Thus, the use of C/P ratios have helped in the practical formulation of poultry feeds.

From the standpoint of economy, the energy content of feed is the most important single consideration in reducing feed costs of meat and egg production. This is true because birds consume more low-energy than high-energy feed to produce the same number of eggs or pounds of meat. Feeding light weight oats instead of corn to high-producing, light-breed layers is a mistake. The increased energy content of the corn improves feed efficiency. This more than offsets out-of-pocket savings apparent for the light oats. Since both oats and corn are palatable to birds, difference in energy content is the major economical consideration. Oats average 700 to 800 Cal per lb; whereas, corn contains 1,150 Cal per lb. Substitution of 300 lb of oats for corn in a ton of feed reduces total energy by 60 Cal per lb. Birds use less high-energy than low-energy feeds to produce the same number of eggs or pounds of meat. Energy levels in feed for egg production, growth, and fattening are in many instances the limiting nutrient on maximum efficient performance.

SHOULD FEEDS CONTAIN MANY DIFFERENT INGREDIENTS

Modern formulas that call for 15 different ingredients are fairly common and occasionally one encounters lists that contain several dozen or more items. There is no special virtue in using a large number of ingredients in making formula feeds. The use of a large number of ingredients in making a formula feed does not give any assurance that the final product will be adequate in every way. None of the organic elements or mineral elements can be synthesized by an animal. They all must be present in the feed that is consumed. On the other hand, some of the amino acids and vitamins can be synthesized by the growing animal if the necessary materials are present in the feed.

There are many interesting relationships among nutrients in poultry nutrition. For example, rickets is produced by feeding too much calcium, as well as too little phosphorus. The formulation of a truly good formula feed is not a simple matter. Ingredients must be plentifully supplied with necessary nutrients in proper quantities and in available form useful to

the animal. To be useful to an animal, nutrients must be biologically available. Availability may depend on digestibility, absorption or tissue transport. Dietary factors affected are solubility of the nutrient, the presence of binding agents, and possible metabolic antagonists in the feedstuffs.

ENERGY REQUIREMENT

The energy requirement of birds is met entirely by the chemical energy contained in the feed. The energy retained by the body is metabolizable energy (M.E.) amounting to 70 to 90% of the gross energy depending on a number of factors. The absorption of energy from the gastrointestinal tract is followed soon after by an increase in heat production, referred to as the heat increment, calorgenic effect, or the specific dynamic action (S.D.A.). The amount of heat produced by a bird in a given time is measured by direct and indirect means. The direct method involves inclosure of the animal in some form of calorimeter and the measurement of the temperature change of the air circulating through the walls of the calorimeter. This measures the total amount of heat lost from the animal; if the body temperature does not change during the course of the measurements, the heat loss will be the same as the heat production.

A recent development is the gradient layer calorimeter which measures the nonevaporative heat loss from the bird. This gives a temperature difference across a gradient layer incorporated in the walls of the calorimeter. From the temperature difference, the heat flow can be obtained. This gives a fast response and a continuous record of heat loss.

Calorimeters are complex instruments and are expensive. Heat production can be measured more simply by indirect calorimetry. The amount of oxygen consumed by the bird in a given time is measured and the heat production is calculated from the oxygen consumption. The respiratory quotient (R.Q.) is calculated. This is the ratio of carbon dioxide produced to the volume of oxygen consumed in a given time. In the case of carbohydrate, the R.Q. is one. With pure fat it is 0.71, and protein 0.73. Values for fat and protein are low because their molecules contain less oxygen and, therefore, require more oxygen for combustion than do carbohydrates. Measurement of oxygen consumption is usually made by enclosing a bird in a chamber through which air flows at a constant rate. The air leaving the chamber is passed through an automatic carbon dioxide and oxygen gas analyzer. From the rate of flow and the difference in oxygen, carbon dioxide content of the air entering and leaving the chamber, the rate of oxygen consumption, and carbon dioxide production can be calculated. The amount of food consumed and feces produced are measured and their energy content determined. The amount of energy absorbed from the intestinal tract can be measured.

The energy retention of a group of animals over a period of time can be obtained simply by killing half of them at the start of the experiment and the other half at the end of the experiment. The caloric values of the carcasses of both groups are determined. This is known as the comparative slaughter method and is particularly suitable for small animals. Different breeds of chickens have different rates of heat production. White Leghorns have a higher heat production than Rhode Island Reds which, in turn, produce more heat than New Hampshire Cornish breeds. When birds are deprived of feed, their heat production diminishes. The R.Q. diminishes because fat is preferentially metabolized during starvation. When chickens are fed a sufficient amount of food to maintain constant body weight on a so-called maintenance diet, their heat production is approximately 50% greater than their standard metabolic rate. When birds are exposed to environmental temperatures below their critical temperature, their heat production may be 3 or 4 times greater than normal. The heat production is brought about largely by shivering. The food intake of birds on a low-energy diet is greater than those fed on a high-energy diet. The feed intake of chickens is also affected by the environmental temperature. Energy is stored partly as glycogen in the liver but mainly as fat. Forcibly fed geese are able to deposit fat at the rate of 3 gm per hr. Growth rate

TABLE 13.1

METABOLIZABLE ENERGY VALUES OF COMMON FEEDSTUFFS FOR CHICKENS

Feedstuff	Metabolizable Energy: Average (Cal per lb)	Metabolizable Energy: Range (Cal per lb)
Corn	1600	1550–1670
Hominy feed	1320	1190–1530
Milo	1500	. . .
Wheat	1520	1480–1570
Wheat red dog	1270	. . .
Wheat flour middlings	1220	. . .
Wheat stand. middlings	840	. . .
Wheat bran	540	. . .
Oats	1210	1130–1290
Barley	1310	1260–1400
Rye (Tetrapetkus)	1330	. . .
Molasses (blackstrap)	910	. . .
Soybean oil meal, 44% protein	1030	970–1110
Soybean oil meal, 50% protein	1110	990–1160
Meat scraps (50–55%)	910	860–1190
Corn distillers solubles	1300	. . .
Dried whey	850	810–860
Alfalfa meal	640	530–880
Stabilized tallow	3300	. . .
Lard	3960	. . .
Corn gluten meal	1475	. . .
Corn oil	3975	. . .

of chicks is adversely affected by cold wind because heat loss is accelerated and energy that would otherwise be available for growth is used to maintain body temperature.

Energy is the most important large single factor required in poultry feeds (Table 13.1). Life itself is dependent on many catabolic and anabolic energy interchanges involving oxidation and hydrolysis of various reversible and irreversible types. A major factor in poultry production is the extent to which energy or its equivalent is upgraded from feedstuffs into materials useful to poultry and on an economically competitive basis.

As has been indicated previously, energy is not a nutrient. It is an important function of some nutrients. It is fuel for the maintenance of body temperature, movements of the body, digestion, and utilization of feeds. All life processes depend on the energy from the feed that is eaten (Table 13.1).

SOURCES OF ENERGY

Carbohydrates and fats are the main sources of energy. Proteins can furnish energy too, but they are more valuable for their amino acids. These nutrients are manufactured by plants which derive and store energy from the sun. When plant products are consumed by poultry, digested, and their nutrients absorbed, the latter can be deposited in the body or broken down into CO_2 and water with a subsequent release of energy. Both carbohydrates and proteins contain 4 Cal per gm; fats produce 9 Cal.

Only that portion of the total energy value of a feedstuff that can be utilized by the chicken is useful. Corn and wheat are high-energy grains, barley and heavy oats, medium energy; and light oats, low energy. Poultry eat primarily to satisfy their energy requirement. If a ration is diluted with inert material (such as high fiber ingredients) poultry will, up to a point, increase feed intake. A borderline nutrient deficiency in the original ration, thus may be offset by increased feed intake. If the energy value of the feed is too low, added protein will be used for energy rather than for tissue building, a more valuable role. If the protein content of the feed is too low, increased energy does not improve growth because protein is inadequate.

Energy is the fuel for the animal body expressed in calories. Energy consumed by the animal is dissipated as heat or stored in the body; the latter can be measured by the heat produced on burning it. The total energy value of a feedstuff is not used in its entirety by the animal. It can be partitioned as follows: gross energy (total heat value) less energy of feces equals digestible energy, less energy of urine equals metabolizable energy, less energy cost of utilization (specific dynamic effect) equals net energy or productive energy. Theoretically, net energy should be the more useful

TABLE 13.2

THE EFFECT OF DIETARY ENERGY LEVEL ON GROWTH, FOOD INTAKE, CALORIC INTAKE, AND FAT CONTENT OF CHICKS

	Basal Diet				
	High Calorie	Plus 10% Hulls	Plus 20% Hulls	Plus 30% Hulls	Plus 40% Hulls
Energy level (Cal per lb)	975	858	741	623	505
Calorie-protein ratio	49	43	37	31	25
Avg weights 11 wk (lb)	3.28	3.26	3.35	3.21	3.20
Avg feed consumption 11 wk (lb)	9.6	9.7	10.8	11.2	12.0
Avg calorie intake 11 wk (Cal)	9470	8400	8100	7090	6160
Fat content of males, dry basis 11 wk (%)	26.8	23.2	21.1	18.1	16.1

measure of feedstuffs because it takes into account all the energy losses incurred by the animal. Unfortunately, these values are quite variable because they are influenced by several factors: balance of the ration, plane of nutrition, and productive purpose. Metabolizable energy values are less subject to these influences.

The requirement for energy is divided between maintenance and production. The former includes the basal heat production plus the energy needed for activity. The latter is energy for growth and egg production. The requirement for maintenance is greater than that for production and takes precedence over it. The minimum energy requirements for chicks for early growth is 800 to 850 Cal per lb for rations composed of ordinary ingredients. Bulk is a factor which greatly influences feed intake and as a result, pelleting or crumbling is more likely to improve a bulky ration than a high density feed. Growing chicks regulate their feed intake largely although not entirely according to the energy level of the ration and compensate to a large degree for a low energy level by an increase in feed consumption. High energy rations produce a caracass that is high in fat which is generally associated with succulence, flavor, and pigmentation. All factors favor the use of as high a level of productive energy in rations as is economically feasible.

Early work showed that corn and wheat are superior to barley and oats in fattening rations. These data are consistent with the known higher energy values of corn and wheat. The relation of energy level to feed intake must always be kept in mind. A high feed consumption may lead to a higher pro-

tein intake which may be responsible for improved growth and feathering. In laying birds, feed intake decreases as dietary energy level is raised so that productive efficiency increases so long as productive level is maintained.

The use of pellets in feeding hens generally increases the level of feed consumption and helps generally to maintain greater body weight. Pelleting tends to improve low energy feeds. Although the hen adapts its feed intake to compensate for differences in dietary energy level, the use of rations low in energy entails a sacrifice in efficiency of egg production. For maximum production and weight maintenance, 900 Cal per lb of total ration appears to be proper for laying hens. Lower levels may be sufficient in warm weather or when pellets are fed.

ENERGY VALUES AND FEED FORMULATION

A knowledge of energy values for feed ingredients is necessary in order to formulate economical rations, especially for the programming of least-cost formulas. Some tables list both productive energy and metabolizable energy values of feedstuffs, whereas others list one or the other. This has tended to confuse poultrymen because they often do not know which energy value to use. As stated, net energy values are preferable, but since the net energy value of a given feed varies according to its use, it is difficult to list values for all the energy functions of a feed. Metabolizable energy can be more precisely measured than productive energy. Under reasonably standardized dietary conditions, metabolizable energy values are reproducible, little affected by nutritional balance, highly correlated with performance, not markedly influenced by genetics, and relatively easy to determine. Productive energy values are not readily reproducible, not influenced by nutritional balance and density of feed such as pelleting, and are very markedly influenced by genetics. The productive energy value of a ration is approximately 70% of the metabolizable energy value. Excess energy in the developing pullets ration during the tenth week and the onset of egg production leads to premature fattening that impairs reproductive performance. Energy levels in feeds can be regulated to some extent by using varying amounts of oats and corn in the feed.

Corn is used as the main grain source in poultry feeds since it provides more value per feed dollar in midwestern states than does oats or wheat. Corn contains 25 to 35% more productive energy than oats and usually costs from 35 to 50¢ less per 100 lb. While energy value is the same for old or new corn, feed manufacturers generally combine new and old corn based on available supplies in order to offset the loss of nutrients and reduction in palatability of stored corn.

has less protein, draws flies, and is difficult to handle, it is not used very extensively in poultry feed. Fats, as stated, are potent sources of energy, containing 2,900 Cal per lb of productive energy. This is 2½ times as much as in corn.

The net energy value of a feed for the mature chicken is obtained by using calorimetry to determine the heating effect (specific dynamic effect) and subtracting this from the metabolizable energy. Fraps made extensive studies of the productive (net) energy values of feeds in feedstuffs for growing chickesn using a slaughter technique. The metabolizable energy determinations are particularly well suited for the chicken and other poultry since undigested feed residues and urinary excretions are voided together. Energy is the most costly component of rations: 100 lb of modern egg mash contains (wholesale prices) 8¢ worth of vitamins, 10¢ worth of minerals, 80¢ worth of protein, and 145¢ worth of energy.

TABLE 13.3

ENERGY VALUES OF FEEDSTUFFS

Class of Feedstuff	Cal per Gm of Digestible "Conventional" Protein (6.25 × N)
Animal Products	
Casein	4.35
Eggs	4.35
Fish	4.25
Gelatin	3.30
Meat	4.25
Milk	4.40
Cereals and cereal products	
Barley	4.00
Corn	4.40
Millet	4.00
Oats	4.00
Rice	4.10
Rye	4.00
Sorghum grains	4.40
Wheat	4.00
Wheat bran	4.20
Legumes	
Alfalfa (leaf and stem)	3.65
Beans	4.30
Peanuts	3.60
Soybeans	3.90
Other	
Sunflower seed	3.40

A ratio of energy to protein exerts an influence on feed intake and feed efficiency. As the protein (amino acid content) is lowered in isocaloric rations, the total amount of feed consumed is increased and the feed efficiency is reduced. Thus, growing chicks are able to maintain similar growth rates as measured through a fairly wide range of C/P ratios. When the pro-

TABLE 13.4

METABOLIZABLE ENERGY VALUE OF DIGESTIBLE NITROGEN-FREE EXTRACT

Class of Feedstuff	*Cal per Gm of Digestible* Nitrogen-free Extract
Grains, and most other seeds	4.2
Legume seeds (e.g., soybean) & rice byproducts	4.0
Meat and fish by-products	3.9
Legume leaves and stems (e.g., alfalfa)	3.8
Milk by-products	3.7
Total energy value of carbohydrates	
Carbohydrate	Cal per Gm
Pentoses and pentosans	3.72–4.38
Hexoses	3.75–3.86
Sucrose	3.96
Dextrin	4.11
Glycogen	4.19
Starch	4.20
Cellulose	4.20
Total energy value fats and oils	
Meat, fish and eggs	9.50
Dairy products	9.25
Cereals, vegetables, and fruits	9.30

tein deficiency stress can no longer be overcome by increased feed intake, then differences in growth rate are observed. This increase in feed intake results in an increased energy intake and a greater deposition of fat in the carcass amounting to 2½% increase in the body fat of chicks 4 weeks of age from widening the C/P ratios from 35 to 70 with essentially no effect on rate of gain. Thus, the C/P ratio influences overconsumption of feed and body composition (Table 13.5).

TABLE 13.5

SUGGESTED CAL-PROTEIN RATIOS[1] FOR POULTRY

	Metabolizable	Productive
Broiler starter (0–5 wk)	60–65	42–45
Broiler finisher (after 5 wk)	69–75	48–53
Chick starter (0–8 wk)	63–66	44–46
Chick grower (8–18 wk)	77–86	54–60
Layer, 50% production	91–94	64–66
Layer, 70% production	84–87	59–61
Layer, 90% production	80–83	56–58
Turkey starter (0–6 wk)	43–46	30–32
Turkey grower (6–12 wk)	57–60	40–42
Turkey grower (12–18 wk)	71–74	50–52
Turkey grower (18–24 wk)	85–100	60–70
Turkey finisher	100–105	70–72
Turkey breeders	86–91	6–64

[1]C/P ratio is defined as $\frac{\text{kcal per lb}}{\text{\% Protein}}$.

The importance of the relationship between energy content and protein (amino acid content) of feeds has been demonstrated. It must be remembered, however, that this is only an example of the other relationships with other nutrients which must be correlated with the energy content.

Suboptimum energy densities on full feeding are conducive to increased feed consumption to compensate for energy dilution in a ration (Table 13.6). Ration balances are of basic importance in realizing maximum value for any given level of feed energy. Chicks suffer more than a 6% loss in efficiency of M.E. utilization when insufficient thiamine is present in a ration. Biotin is necessary for oxidative glucose phosphorylation, for adequate energy in the body and for normal protein synthesis. The lowest cost calories are provided as starch contained in common farm grains and grain by-products. Where additional energy is still required for maximum performance, fats or oils are added to feeds. Energy from sugars is the most expensive source and is most often employed to enhance palatability or aroma of feed. In essence, energy metabolism represents a conversion of complex sugars, starches or fats to glucose to provide energy necessary to produce meat or eggs.

TABLE 13.6

EFFECT OF ENERGY LEVEL ON FEED REQUIREMENTS AND BODY WEIGHT OF LAYERS

Productive Energy Cal per Lb	Lb Feed per Dozen Eggs	% Egg Production	Body Wt of Layers (Lb) at 5 Months	at 14 Months
740	5.74	64.9	. .	. . .
840	5.19	66.9	. . .	. . .
945	4.62	66.5	4.36	4.61
985	4.35	69.5	4.24	4.63
1025	4 16	70 9	4 34	4.71

University of Connecticut researchers have shown that the feed cost per 1,000 broilers is increased approximately $30 by increasing the productive energy content of the broiler formula from 835 to 904 Cal. The rate of egg production in cold weather is increased significantly by increasing the productive energy content of the diet. Such an effect is not as pronounced during warm weather.

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Properties of Vitamins

FAT SOLUBLE VITAMINS

Introduction

Nutrition researchers from around the country cooperate with National Research Council in publication of their findings. From their work, for example, they may state that a bird requires so much of a nutrient to perform in a certain way and from that a minimum requirement may be deduced.

Discovery of vitamin D was of considerable and very practical importance to poultrymen because for the first time chicks could be reared at any time of the year regardless of climatic conditions and laying hens could be kept in strict confinement.

The vitamins can be divided into two groups—the fat-soluble and the water-soluble. Among the fat-soluble vitamins is vitamin A which all animals and people must have for good health and vitamin D which prevents rickets in young animals and is essential in maintaining good bones. Vitamin E, or alpha tocopherol relates to fertility and reproduction. Fortunately, most of our foods have sufficient of this so it is not a big problem. The fourth fat-soluble vitamin is vitamin K or the antihemorrhagic vitamin.

Vitamin A is a pale-yellow, fat-soluble organic compound found chiefly in animal tissues, *i.e.*, fish liver oil has high levels of vitamin A activity. Vitamin A not only comes from animal products but can be obtained from plant products as well. The yellow color of corn and carrots, for instance, is carotene which has provitamin A activity. They call carotene provitamin A; the animal changes it to true vitamin A.

After vitamin A and carotene are consumed hydrolysis takes place in the small intestine and the free vitamin is transferred through the gut wall. Vitamin A promotes growth and health. If there is a deficiency of vitamin A, growth is inhibited. If you put back the nutrient, growth is improved and therefore, it is "growth promoting."

Vitamin A increases resistance to some infectious diseases. It is used quite frequently in coccidiosis. It is necessary for good egg production, fertility, and hatchability. It helps maintain normal functioning of the epithelium and nerve tissues. Vitamin A deficiency in chicks usually develops during the 3rd and 4th week; growth starts to slow down and drowsiness, staggering gait, and incoordination of movement accom-

panied by weakness become evident. Emaciation and ruffled conditions of plumage occur. Some chickens develop what is called xerophthalmia, a condition in which the eyes appear dry and pale. Death results before the end of the fifth week. In posting these birds, lesions in the mouth and upper respiratory tract are present, and there is an accumulation of urates in the kidneys and ureters.

Feedstuffs which contain vitamin A activity are alfalfa meal, yellow corn, and corn gluten meal. Synthetic vitamin A is inexpensive. Vitamin A is usually added to the ration in addition to what is contained in the natural feeds which provides a margin of safety.

Vitamin D is mainly concerned with proper metabolism of calcium and phosphorus. There are several forms of vitamin D. One of the most common is called vitamin D_2 from irradiated ergosterol. Chicks can use to some extent vitamin D_2 but it would be uneconomical; however cattle use D_2, since it is economical.

The classical vitamin D work was done on the chick because they are actively growing and their bones grow so fast that if there is interference with the calcium-phosphorus metabolism in the bones, there will be crooked bones. It is much more difficult to produce a deficiency in an adult whose bones are developed.

Some of the functions of vitamin D are the control of calcium and phosphorus equilibrium. It is specific against rickets. The word "rickets" comes from a word that was used in the past "wricket", which means a twisted bone. Deficiency symptoms of vitamin D are rubbery bones and beaks, lameness, reduced growth of skeleton, thin egg shells, reduced egg production, and poor hatchability.

Sources of vitamin D are fish liver oil, synthetic vitamin D, and irradiated ergosterol.

VITAMIN CHRONOLOGY

Year	Vitamin	Discoverer, Product, and Animal
1897	Thiamine	Ejikman—polyneuritis, chick
1913	A	McCollum, Osborne, and Mendel—lipins, rats
1915	Thiamine	McCollum, Davis—"A" rat factor
	A	McCollum, Kennedy—"A" rat factor
1916	Thiamine	McCollum, Kennedy—water-soluble B
	A	McCollum, Kennedy—fat-soluble A
1919	A	Steenbock—plant pigments, rat
	A	Palmer, Kempster—not carotenoid, chick
	D	Huldschinsky—UV irradiation

1922	D	McCollum—discovery rat
	E	Evans, Bishop—factor X-, rat
1923	D	Bethke—bone ash, rat
1924	D	Steenbock, Black—irradiated food and D, rat
	Biotin	Boas—egg-white disease, rat
1925	D	Hess—irradiated cholesterol, rat
1926	Thiamine	Jansen, Donath—crystalline vitamin
	A	Beach—deficiency, chick
	Riboflavin	Smith, Hendrick—evidence, rat
1927	D	Rosenheim, Webster—ergosterol, rat
1928	Riboflavin	Hogan, Shrewsbury, Kempster—curled toes, chick
	Pyridoxine	Hogan, Hunter—deficiency, rat
1929	A	V. Euler—carotene
	Pyridoxine	Chick, Roscoe—evidence, rat
	K	Dam—chicks
1930	A	Moers—conversion carotene to A, rat
	D	Mussehl, Ackerson, Massengale, Nussmeier—ergosterol not for chick
	Biotin	Norris, Ringrose—dermatitis, chick
	Riboflavin	Norris, Heuser, Wilgus—curled toes, chick
	Pantothenic acid	Norris, Ringrose—dermatitis, chick
1931	E	Pappenheimer, Goettsch—deficiency, chick
	Biotin	Gÿorgy—vitamin H, rat
1932	Pantothenic acid	Kline, Kennan—dry heat dermatitis, chick
	Choline	Best, Huntsman—fatty liver, rat
	B_{12}	Byerly, Titus, Ellis—animal protein for laying hens
1933	Riboflavin	Kuhn—isolation
	K	Holst, Halbrook—deficiency disease, chick
1934	D	Waddell—irradiated cholesterol, rat, chick
	K	Dam—discovery, chick
1935	D	Windaus—7-dehydrocholesterol
	Riboflavin	Kuhn—synthesis
	Pyridoxine	Gÿorgy—evidence B_6, rat
	Pantothenic acid	Elvehjem, Koehn—antidermatitis factor, chick
	Folic acid	Wills, Day—monkey

1936	Thiamine	Williams, Cline—structure synthesis
	E	Goettsch and Pappenheimer—vegetable oil, chick
	E	Evans, the Emersons—isolation
	Biotin	Kogl, Tonnis—crystalline
	Riboflavin	Lepkovsky, Jukes—crystalline B_2, chick
	K	Dam *et al.*—low prothrombin
	Pantothenic acid	Lepkovsky, Jukes, Krause—factor 2-, rat, chick
	B_{12}	Nestler *et al.*—hatchability factor
1937	Nicotinic acid	Elvehjem—black tongue, dog
1938	Thiamine	Lipschitz, Potter, Elvehjem—function
	E	Dam—tocopherol for the chick
	Pyridoxine	Lepkovsky, Gÿorgy, Keresztesy—isolation Eckhardt—pyridoxine
	Pantothenic acid	Williams—concentrate
	Folic acid	Stokstad, Manning—factor U, chick
1939	K	Almquist, Klose—phthiocol, K_3
	K	Doisy—group isolation
	Choline	Griffith—hemorrhagic kidneys—rat
1940	Thiamine	Jukes, Heitman—symptoms of deficiency
	Biotin	Gÿorgy—vitamin H is biotin, rat
	Choline	Abbott, DeMasters, chick Hogan—perosis, a defic. disease
	Folic acid	Hogan, Parrott—vitamin B_c, chick
	Inositol	Woolley, mice
	Choline	Jukes—perosis and choline, chick
1941	Biotin	Eakin, Snell, Williams—avidin, chick
	Folic acid	Mitchell, Williams
1942	Biotin	Richardson, Hogan, Miller—perosis, chick
	Vitamin B_{12}	Johnson, Carrick—casein, extract for chick
	Folic acid	Mills, Briggs—L casei factor
	Nicotinic acid	Briggs, Mills—required, chick
1943	Folic acid	O'Dell, Hogan—properties Pfiffner, Stokstad—isolation
1944	B_{12}	Hammond—manure factor, chick
1946	B_{12}	Cary—factor X, rat
	Nicotinic acid	Briggs, Groschke—tryptophan and nicotinic acid
1947	B_{12}	Shorb—LLD factor
1948	B_{12}	Folkers—isolation
	B_{12}	Ott—required by chick

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The Nature of Vitamin A.—Vitamin A is the oldest known vitamin, first determined about 35 yr ago. Though the total synthesis was achieved over 25 yr ago, research is still exceedingly active on this vitamin. Vitamin A activity occurs in a multiplicity of forms. There are active derivatives of the vitamin A molecule itself, but also a number of naturally-occurring active carotenoids. Each of the vitamin A derivatives exists in a number of isomeric forms with different biological activities. An isomer is 1 of 2 or more substances which have the same elementary composition but differ in structure and hence in properties. The prefixes *cis* and *trans* refer to the direction of which the side chain of the molecule is bent. Vitamin A has 16 *cis* strain isomers theoretically possible of which only 6 have been synthesized to date. Twenty to thirty different isomers are theoretically possible for each of the major carotenoids. The all-trans isomer has the highest biological activity and is used as the international vitamin A standard.

Assay.—The Carr-Price method of assay does not differentiate between the isomers, since it gives the same blue color with each. Lower biopotency is exhibited by isomers other than all-trans. When one divides micrograms of carotene by 0.6 to obtain units of vitamin A activity, one is assuming that only all-trans beta carotene is present. Consequently, values which have been derived from carotene are erroneously high. More research is needed to establish and improve the applicability of existing methods to commercial feed products. Only animal bioassays provide a reliable picture of biopotency in commercial feed products containing many isomeric mixtures. Chick assay is more valuable in this regard than procedures based on modern instrumentation. It may be concluded that combinations of isomers have less biological activity than an equal number of the pure all-trans isomers. The conversion of carotene values to vitamin A activity using the proper factor of 0.6 is a questionable practice. If pure all-trans vitamin is used for feed supplementation, then 1 Carr-Price unit equals 1

USP unit equals 1 biological unit. The levels of individual isomers of a vitamin A source must be known if assay values are to be interpreted correctly.

Stability.—Carotene stability among feed ingredients and supplements of various kinds vary considerably. Stabilizing or destroying properties are apparent between different ingredients. Thus, carotene stability in mixed feed is a complex phenomenon. For example, losses are high in connection with diets containing trace minerals following storage. Losses are greater with oil than with alfalfa supplement. Meat scraps affect the stability of oil-type carotene to a lesser extent. There is a superiority of alfalfa over oil when meat scraps are present in high trace mineral diets that are stored for some time. A greater overall vitamin A stability is attained with a wax-coated vitamin A supplement than with oil or with fat-type supplements. An antioxidant treatment is effective in increasing vitamin A, carotene and fat stability over that observed when nonstabilized fat or no fat is added. In one test, santoquin was shown to be most effective, followed closely by DPPD, BHT, and BHA plus BHT.

Vitamin A was discovered by McCollum and Davis in 1915, isolated in 1931, and synthesized in 1937; commercial, large-scale production occurred in 1950. Most of the vitamin A activity in fish liver oil is present in the ester form. Liver storage test is used as the criterion of availability of the vitamin. Although there is an improved availability of vitamin A when administered in aqueous emulsions, most of the vitamin A is consumed in the form of an oil, the less available form of vitamin A.

Since this vitamin is sensitive to oxidation, stabilization of vitamin A against oxidative losses is desirable. To stabilize vitamin A in the feed, one product is produced by imbedding crystals of vitamin A in a matrix of gelatin, thus surrounding the tiny granules with a protective coating of gelatin. Particle size governs availability. Superior availability of the gelatin-stabilized vitamin A is claimed over the fish liver oil. The gelatin-stabilized vitamin A acetate is a dry solid and, therefore, of a special utility. It is more stable in mineral mixes, a carrier which normally catalyzes its destruction. Vitamin A in the form of fish liver oil is rapidly destroyed when spread on a finely divided feed. The gelatin-stabilized form of vitamin A is not subjected to accelerated decomposition as is the vitamin A in fish liver oil when exposed on an extremely large surface and catalyzed by the presence of minerals.

Dietary nitrate and/or nitrite accelerates vitamin A depletion from body stores. Toxic levels of nitrates in forages depend upon the age and health of the animal, type of forage, rate of feed intake, species, and energy level of the ration; 3,000 ppm of nitrate on a dry matter basis is the upper safe

limit in feeds. Drinking water is potentially dangerous if it contains 50 to 100 ppm of nitrates. Carotene is an unstable source of vitamin A activity in natural feedstuffs. Alfalfa loses up to 80% of its carotene while curing; sun-cured hays lose over ½ their carotene content in 3 months storage; and corn loses over ½ during 6 months storage.

Biological Availability.—Factors controlling the biological availability of vitamin A are the size of the vitamin A particles and the carrier containing the vitamin A—whether it is oil, wax or gelatin. Vitamin A stability losses result from high moisture, pelleting steam, some minerals, particularly the water-soluble salts, trace minerals, such as copper, iron, manganese, zinc, and iodine, and some liquids such as fish solubles, molasses, choline chloride, as well as high temperature. In premixing vitamin A, particle size should be 30 to 100 mesh and bulk density 47 lb per cu ft. Moisture content should be low, if the feed is to be stored for an extended period. One to three percent added fat or oil prevents oxidation or rancidity.

Minimum vitamin A requirements are markedly increased when higher protein diets are fed. No brain lesions are observed in chicks suffering from vitamin A deficiency. Vitamin A nutrition above minimum levels needed for growth is of primary importance for prevention of severe lesions and losses from CRD and coccidiosis. Minimum levels of vitamin A required for growth and feed conversion under excellent environmental conditions is short of the amount needed to provide fullest integrity of the mucous epithelium and sufficient liver storage for periods of emergencies such as outbreaks of coccidiosis or CRD.

The superiority of present feed mixtures has been adequately proved, particularly in broiler production. Although animals have been fed for many thousands of years, modern broilers are less than half a century old and were made possible by the rapid advances in applied poultry nutrition. Nutritionists are still trying to determine how many more vitamins exist. But the surface has only been scratched as to the fundamental functions of many of the vitamins.

Definition of a Vitamin.—Vitamins are unrelated chemically. They are organic substances required in very small but definite amounts in the diet for the maintenance of health and normal functioning of the body. These functions include maintenance of body weight, growth, fattening, reproduction, lactation, egg production, activity, and metabolic processes such as digestion, absorption, and excretion. Characteristic nutritional deficiency symptoms occur in their absence.

The Need for Vitamins.—For the most part, vitamins serve as parts of enzyme systems which catalyze specific biochemical reactions occurring in different cells of the body. The animal body fails to function if it lacks any one of the required vitamins. Vitamins are divided into groups—those

which are soluble in fat solvents (fat-soluble vitamins) and those which are soluble in water (water-soluble vitamins). The latter are members of the vitamin B-complex, except for vitamin C (ascorbic acid) which is not required in the diet of poultry. The fat-soluble vitamins are A, D, E, and K. Water-soluble vitamins are thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, choline, folacin (folic acid), and cyanocobalamin. This list does not include certain unidentified growth factors required for growth and reproduction. Fortunately, certain vitamins are readily synthesized either in the animal body (vitamin C for example) or in the digestive tract by microorganisms. Monogastric animals such as poultry may obtain nutrients from bacterial synthesis, but the amounts are variable and cannot be depended upon. From a standpoint of practical application in feeding, those vitamins which are nutritionally essential must be furnished by the diet at least in minimal amounts. Poultry require dietary sources of all known vitamins except vitamin C, inositol, and para aminobenzoic acid.

More is known concerning the nutritive requirements of the chick than of the adult chickens. Poults have a slightly higher dietary requirement for most vitamins than do chicks. Ducklings and goslings have about the same requirements as the chick. Known vitamin requirements of poultry are published in the National Research Council report, "Recommended Nutrient Allowances for Poultry" which is updated periodically.

Vitamin A and riboflavin levels require special attention in the formulation of any poultry ration. With high energy, practical starting and growing rations, niacin, calcium pantothenate, vitamin B_{12} and choline are added. Vitamins E and K are needed to a lesser extent in certain feeds. Thiamine, pyridoxine, and biotin are supplied at adequate levels in all practical type poultry rations and, therefore, present no problems to feed manufacturers. The level of folic acid also is not likely to be of practical concern since both alfalfa and soybean oil meal are excellent sources. Folic acid deficiencies have been observed, however, with rations composed of commonly used feedstuffs. Vitamin E is a dietary essential for chickens and is of practical significance at times despite the fact that it is present in cereal grains. It is very readily oxidized which has made its study most difficult. Vitamin E and niacin are critical nutrients for turkey breeders, ducklings, and goslings. Niacin supplied by wheat middlings is less available to these animals than synthetic niacin or dried brewers yeast. A considerably higher level is necessary when no antibiotic is fed. The niacin requirement is greatly influenced by the tryptophan content of the ration and environmental conditions, and is particularly important for proper feather conditions of broilers.

Where the amount of alfalfa meal is low, the level of vitamin K in practical broiler rations may be below optimum. Some of the drugs used in

broiler rations increase the requirement for vitamin K because the K synthesis which normally occurs in the intestinal tract of the chick is reduced. The choline level in the diet must be considered when higher fat rations are used. High producing hens, particularly of the lighter breeds, require higher levels of protein and certain B-complex vitamins than poor producers.

Carryover of nutrients from dams to offspring is important in the nutrition of the chick. Higher levels of vitamin B_{12} and folic acid are required for the production of good quality chicks than is needed just for good hatchability. Applied stress requires higher levels of certain nutrients. Dietary requirements determined with chicks growing in battery brooders or in small floor pens may not be adequate when chicks are raised under conditions of environmental stress and disease.

Unidentified Factors.—Chicks need at least two distinct unidentified factors for rapid growth. One is referred to as the "fish factor" and is supplied by condensed fish solubles, fish meal, unextracted liver meal, crab meal, and fermentation products. The other is called the "whey factor" and is present in dried whey products, dried brewers yeast and distillers dried solubles. Both factors are of practical importance.

In severe vitamin deficiencies, characteristic symptoms develop which make the diagnosis relatively easy. However, field outbreaks ordinarily do not involve severe deficiencies, but rather only suboptimal intakes of these nutrients so that characteristic symptoms do not develop. Field symptoms may be only poor growth, decreased egg production, rough feathering or hair growth, and poor reproduction. It is important in practice to diagnose properly any nutritional deficiency as soon as possible. This makes it desirable for veterinarians, feed servicemen, poultrymen, and livestock producers to be familiar with the early symptoms of different vitamin deficiencies.

Vitamin A, as the alcohol, acetate or palmitate, is synthesized and is rapidly destroyed by oxidation unless it is protected in an oil solution or by other means. Fish oils range as high as 600,000 units of vitamin A per gram. Dry vitamin A preparations consist of vitamin A oil dispersed in a dry carrier. Most such products are protected with a coating of hydrogenated fat, wax, gelatin, pectin or protein-starch combination. Destruction of vitamin A is accelerated by heat, light, moisture, minerals, unstable fats or oils and surface exposure, especially on impermeable substances such as the minerals. Destruction is slowed by the presence of protective agents such as natural oil, added antioxidants, and antioxidant-treated greases and tallows.

Effect of Pelleting on Vitamin A.—Pelleting may accelerate destructive influences due to the heat and moisture used in the process, especially if

the pellets are not properly cooled. Vitamin A kept in the drum is relatively stable but loss is rapid when it is mixed in the feed. Storing in inert gas and under refrigeration reduces losses in dehydrated alfalfa to practically zero. Also, small amounts of an acceptable antioxidant plus sufficient oil, fat, tallow or grease, and pressure to assure adequate permeation of all particles greatly retard loss of vitamin A activity in alfalfa meal.

The Use of Antioxidants.—Addition of an antioxidant to the oil will be of only temporary and slight benefit after it is mixed in the feed. Coatings must be readily digested or disintegrated in the digestive tract to permit release of the vitamin A for absorption through the intestinal wall. An antioxidant should be present that will aid in protection of vitamin A in the intestines after the vitamin is released from the protective coating. The wax-coated product has given good results but even the best product is susceptible to destruction.

Vitamin A concentration in the blood is related to the vitamin A intake. A high storage of vitamin A in the liver is not essential for satisfactory growth provided sufficient vitamin A is supplied in the daily diet.

Losses of Vitamin A During Storage.—Manufacturers of alfalfa meal try to produce a high carotene meal by cutting at the right age when weather permits, and curing or dehydrating at proper temperatures, and then storing in cool temperatures. Some feed manufacturers buy alfalfa meal on the basis of its carotene content subject to a penalty in price if it falls below a minimum level. Some poultrymen and even some veterinarians assume that unless they can see visual external evidence of vitamin A deficiency in the eye or throat of the bird, there is no vitamin A deficiency. As a matter of fact, many birds die each year from vitamin A deficiency that show no evidence whatever in the eye or throat. Vitamin A deficiency usually is indicated in the kidneys before the throat and eye are affected. The chick is hatched with a reserve of vitamin A in the yolk sac and the liver. Requirements of growing chicks are based on studies of birds at eight weeks of age, thus allowing time for the reserves to become exhausted. Excessively high vitamin A intake depresses growth. Xanthophyll, a natural yellow pigment of the fowl has nothing to do with nutritional status. Xanthophyll, a pigment in green feed does not serve as a source of vitamin A in the chick. Yellow corn is a fair source of fat-soluble vitamin A but white corn is not.

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Vitamin D

Vitamin D can be supplied to poultry in several ways. By supplying vitamin D_3 in the feed or by irradiating the animal with sunlight or ultraviolet light. Vitamin D_3 is formed in the skin of the animal from 7-dehydrocholesterol on exposure to light at the wavelength of 235 to 315 mμ. Vitamin D_3 is of equal biologic value to man, poultry, and four-footed animals. This is in contrast to vitamin D_2 (calciferol) which is formed by the ultraviolet irradiation of plant sterol, ergosterol (activated ergosterol). If poultry are kept outdoors, sunshine usually provides enough vitamin D for chickens from April to November. During the remainder of the year, sunshine will generally prove inadequate or impractical because of outdoor conditions. For chickens confined indoors, it is necessary to provide vitamin D in the feed or use sunlamps.

The sun bombards the earth with rays of many kinds, both harmful and beneficial. More than half of the radiant energy from the sun is received as light which is visible to the human eye. Another 40% we cannot see but are aware of as heat. Of the sun's radiant energy that penetrates the earth's atmosphere, 5% is ultraviolet radiation. It is this ultraviolet region of the sun's spectrum which is chiefly responsible for the tanning and burning of skin and also stimulates production of vitamin D in the body.

The human eye perceives a narrow band of irradiation called light, but in the spectrum of the sun there are other wavelengths invisible to the eye. All interact with the earth's atmosphere. The radiation received by the human eye as light flows from the sun's protosphere down to the earth's atmosphere where intercepted by moisture, they reflect into all the colors of the rainbow. Then longer wavelengths which are invisible are detected by the human skin as heat and radiowaves. It is the ultraviolet layer which is the agent in the development of vitamin D_3 in the skin of the animals. Chickens housed behind ordinary window glass do not obtain the anti-

rachitic vitamin because ordinary glass screens out the ultraviolet rays even though it permits the light rays to pass through.

Certain chemical compounds known as sterols can be irradiated with ultraviolet light to form vitamin D that compares with cod liver oil in effectiveness. For poultry, the sterol used is an animal sterol such as 7-dehydrocholesterol. The material is incorporated in an edible powder carrier which is added to the feed. The poultry industry could not maintain its present level of production if vitamin D supplement was unavailable. It is an essential, if the poultry industry is to continue on a year-round basis. Long ago, when chickens roosted in trees and lived on bugs and green leaves, the percentage of eggs that hatched was not especially important. The first difficulty encountered when year-around egg production was attempted in confined quarters was the development of vitamin D deficiency. During winter months, just when eggs are wanted for the incubation season, hatchability drops to an uneconomical low percentage if there is no vitamin D in the feed. For many years, poultrymen knew that the hatchability of eggs produced during the winter months tended to be low if birds were kept indoors but when spring came and the birds were allowed to roam in the sunshine, hatchability increased markedly. Storage reduces the amount of vitamin D in feed as shown in Table 14.1.

Years ago, chicks were fed flowers of sulfur to prevent coccidiosis. This drastic treatment caused a vitamin D deficiency along with some hemor-

TABLE 14.1

EFFECT OF STORAGE ON VITAMIN D ADDED AS FISH OIL TO POULTRY FEEDS

Feed Number	A.O.A.C. Units Vit. D per 100 Gm Feed Fresh	3 Mos	Difference (%)
A.O.A.C. basal	25	25	0
B-79	78	72	7.7
B-80	26	21	19.2
B-94	60	53	11.7
B-107	32	29	9.4
B-128	90	86	4.4
B-130	57	42	26.3
B-131	82	88	+7.3
B-132	49	44	10.2
B-133	83	60	27.7
B-143	99	98	1.0
B-194	80	50	37.5
B-195	80	52	35.0
B-199	127	135	+6.3
B-212	133	133	0
B-213	80	11	13.7
B-214	117	107	8.5
B-240	90	45	50.0
B-241	135	130	3.7
B-393	43	12	72.1
B-394	40	24	40.0

rhages. When other more effective products came along to prevent coccidiosis, the sulfur treatment was discontinued to avoid the rickets produced.

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Vitamin E

Vitamin E, or alpha tocopherol, functions as a specifically required vitamin as a part of an enzyme system and as a biological antioxidant. Deficiency of vitamin E in the chick produces encephalomalacia and exudative diathesis. This is a softening of the brain, swelling or thickening of the mouth glands, and muscular dystrophy.

Since encephalomalacia reflects a need for a biological antioxidant, this explains why vitamin E acts in this role. Other substances such as the easily oxidizable unsaturated fatty acids increase the vitamin E. requirements. Synthetic antioxidants may also decrease this requirement. There are a number of synthetic antioxidants. Ethoquin or santoquin prevents encephalomalacia in chicks by preventing oxidation. But it failed to prevent the exudative diathesis or the muscular dystrophy among chicks. Vitamin E can handle that phase of the condition. Recent research on antioxidant properties of vitamin E indicates that at least one important function is the oxidation of fat, not only in the diet of the animal but also as a biological function within the animal.

There is evidence that the prevention of encephalomalacia in chicks prevents vitamin E functioning as a biological antioxidant, expecially related to linoleic metabolism. Alpha tocopherol is provided in many diverse feed-

stuffs. When consumed by animals, it functions as an antioxidant and is nature's way of controlling encephalomalacia in chicks.

Vitamin E is fat-soluble, unstable in the presence of ultraviolet and oxygen, decomposes in storage if not protected from light and air, and is destroyed by iron salts. Rancidity in fats or oils can also affect vitamin E.

Vitamin E is sometimes called the antisterility vitamin. In females, it exercises a determining role in reproduction and is needed for hatchability of eggs. Some sources of vitamin E are meal and egg yolk. There is no requirement for vitamin E listed by the National Research Council but nevertheless most nutritionists recommend adding vitamin E to the diet. The reason is there are nebulous interrelations with vitamin A, environment, and stress. In addition to poor fertility and hatchability, a symptom of vitamin E deficiency is nutritional encephalomalacia in which a softening of certain portions of the brain occurs, and this produces in chicks so-called "crazy chick" disease or exudative diathesis. There is a crusty exudate on the beaks of the bird and muscular dystrophy. If the vitamin E or vitamin A is low, a stilted or staggering gait occurs in the chick. This "crazy chick" disease is found sometimes in the field, particularly in the East.

Vitamin E is added to turkey and pheasant breeder and starter diets which contain low amounts of alfalfa meal. Alpha tocopherol is the most active form of vitamin E and is available to the feed trade as the acetate which is 1.36 times as active as the DL-alpha tocopherol acetate.

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Vitamin K

Vitamin K is fat-soluble and is called the antihemorrhagic vitamin. It was discovered later than most other vitamins. It is called the antihemorrhagic vitamin because it is needed to maintain the normal clotting time of the blood. In the absence of this vitamin, chicks bleed to death from almost any injury because of the rupture of blood vessel walls. Vitamin K is necessary for the maintenance of the correct amount of prothrombin in the blood. The overuse of certain drugs to prevent or control coccidiosis may also result in hemorrhages, but whether these hemorrhages are the result of interfering with vitamin K metabolism is not yet clear. Green, leafy tissue is perhaps the richest source of the plant form of the vitamin. As little as ½% of commercial dried alfalfa in the diet of the chick will meet normal requirements. An inhibitor of vitamin K is dicumarol which is found in moldy, sweet clover and is used in heart disease to thin the blood so it goes through capillaries easier and blood does not tend to clot.

Field cases of encephalomalacia have been noted in England, Scotland, and the United States in certain flocks—usually under stress. It seems to be primarily a condition of a stress of one form or another, notably overcrowding and mixing of age groups. There are considerable differences in susceptibility breeds and strains and it tends to be greater in males. Light Suffolk stock is more susceptible than some of the other breeds and incidences tend to decline when a flock is closed, presumably because some of the susceptible families are eliminated.

Vitamin K and its relation to the hemorrhagic syndrome in chicks is an interesting topic. Vitamin K is an essential metabolite for chicks but the requirement depends on a number of modifying factors, such as the availability of the vitamin from various feedstuffs, its stability in feeds, gastrointestinal microbial synthesis, and the effect of certain drugs or chemicals in the gastrointestinal (G.I.) tract.

Vitamin K is obtained from the feed but it passes through the G.I. tract where there is a plethora of microbes. Microbes synthesize vitamin K and

supply the animal with substantial amounts. The animal gets what is in the feed plus what the flora of the intestine provides. If there is interference. with the microorganisms in the intestine, for example, sterilizing the gut with drugs influences how much vitamin K the birds get. This occurs in cases of hemorrhagic syndrome.

In former years, fishmeal quality was not so good and organisms were growing in the material providing vitamin K. Fishmeal supplied vitamin K from the fish plus that from the organisms. Alfalfa is a good source of vitamin K, but in an attempt to get more meat in a shorter time, "high energy" diets were used. To produce a high energy diet, high amounts of corn and lower amounts of soybean meal are used in the ration. Soybean meal contains oil, a carrier of vitamin K. If there are lower amounts of vitamin K in the feedstuffs from less alfalfa in the high energy diet and better quality fishmeal with a lower amount of vitamin K, less vitamin K is available to the birds. If the birds fought and scratched each other or if they were manhandled, hemorrhages occur throughout the body of the bird. In reducing the amount of fiber by removing alfalfa meal, vitamin K was being lowered. The use of drugs to control coccidiosis also lowered vitamin K. This resulted in a vitamin K deficiency which was called in the field "hemorrhagic syndrome." Simple addition of vitamin K to the rations protects the birds. This vitamin K deficiency was caused by nutritionists trying to do a better job. But the changes made had more ramifications than had been considered. Today commercial feed manufacturers have increased the level of vitamin K in high energy rations.

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WATER-SOLUBLE VITAMINS

Vitamin B-complex

The term "B-vitamin" covers a number of essential, natural dietary substances which are included in the group because they are water soluble

and are found in significant amounts in yeast and liver (Table 14.2). At first, it was not recognized that yeast contained not one but a multitude of essential substances. As research continued, these were isolated 1 by 1. In

TABLE 14.2

GLOSSARY OF THE B VITAMINS

Name	Synonym or Chemical Name
Adenylic acid	Adenine nucleotide Vitamin B_8
Adermin	Vitamin B_6
Aneurin	Vitamin B_1
Antiacrodynia rat factor	Vitamin B_6
Antialopecia mouse factor	Inositol
Antiberiberi vitamin	*Vitamin B_1*
Anticanitic factor	*p*-Aminobenzoic acid
Antidermatitis chick factor	Pantothenic acid
" rat factor	Vitamin B_6, pyridoxine
Antidermatosis vitamin	*Pantothenic acid*
Anti-egg white injury factor	Biotin
Antigizzard erosion factor	Possibly vitamin B_3
Anti-gray-hair factor	*p*-Aminobenzoic acid
Antineuritic vitamin	*Vitamin B_1*
Antipellagra (chick) factor	Pantothenic acid
" factor	Nicotinic acid Nicotinamide
Anti-spectacled-eye factor	May be inositol, biotin or pantothenic acid
Bios 1	Inositol
Bios 2	Biotin
Bios 2*b*	Biotin
Biotin	Vitamin H
Chick A-P factor	Choline
Choline	Beta-hydroxyethyltrimethyl ammonium hydroxide
Chromotrichia factor	*p*-Aminobenzoic acid
Coenzyme-R	Biotin
Complimentary factor	Vitamin B_6
Factor 1	Vitamin B_6
Factor 2 from liver	Pantothenic acid
Factor B_x	*p*-Aminobenzoic acid
Factor S	Biotin
Factor U	Stokstad-Manning factor
Factor W	Biotin
Factor X	Biotin
Factor Y	Vitamin B_6
Filtrate factor	Pantothenic acid
Filtrate factor 1	Possibly vitamin B_6, nicotinic acid Peters factor
Filtrate factor 11	Pantothenic acid
Folic acid	May be vitamin B_c
Inosite	Inositol
Inositol	Hexahydroxycyclohexane

Name	Synonym or Chemical Name
Lactoflavin	Vitamin B_2
Liver filtrate factor	Pantothenic acid
Niacin	Nicotinic acid
Niacin amide	Nicotinamide
Niamide	Nicotinamide
Oryzamin	Vitamin B_1
Ovaflavin	Vitamin B_2
Panothen	Pantothenic acid
Pellagra-preventative factor	Nicotinic acid Nicotinamide
Polyneuramin	Vitamin B_1
P-P factor	Nicotinic acid Nicotinamide
Pyridoxine	Vitamin B_6
Pellagramin	Nicotinic acid Nicotinamide (+)-alpha, y-dihydroxy,-B,B-dimethyl buryryl-B-alanide
Riboflavin	Vitamin B_2
H-riboflavin	Vitamin B_2
Skin factor	Biotin
Thiamine	Vitamin B_1
Torulin	Vitamin B_1
Trichochromogenic factor	*p*-Aminobenzoic acid
Vitamin B_1	4-Methyl-5-B-hydroxyethyl-N- 2-methyl-4-aminopyrimidyl-(5)-methyl -thiazolium chloride hydrochloride, Thiamine
Vitamin B_2	6,7-Dimethyl-9-(d-l-ribityl)-isoalloxazine, Riboflavin
Vitamin B_3	Probably pantothenic acid Williams-Waterman factor
Vitamin B_4	Reader factor; may be arginine or glycine
Vitamin B_5	Peters factor May be vitamin B_6 or nicotinic acid
Vitamin B_6	3-Hydroxy-4,5-bix(hydroxymethyl)-2-methylpyridine; pyridoxine
Vitamin B_7	Vitamin I
Vitamin B_8	Adenylic acid
Vitamin B_c	May be folic acid
Vitamin B_p	Antiperosis factor
Vitamin B_w	Biotin
Vitamin B_x	Pantothenic acid
Vitamin B_x	*p*-aminobenzoic acid
Vitamin F	Vitamin B_1
Vitamin G	Vitamin B_2
Vitamin G	Pantothenic acid
Vitamin H	Biotin
Vitamin H	Vitamin B_6
Vitamin I	Vitamin B_7
Vitamin L_1) Vitamin L_2)	Lactation vitamins
Vitamin M	Day's factor
Yeast eluate factor	Vitamin B_6
Yeast filtrate factor	Pantothenic acid

the beginning of vitamin research, the field was divided into two parts—oil-soluble vitamin A, and water-soluble vitamin B obtained from yeast and rice polishings, as well as from other natural sources. The water-soluble B fraction was later subdivided into vitamin B_1 which was thermolabile and vitamin B_2 which was thermostable. Vitamin B_2, as originally designated, turned out to be not a single substance. Although at least 12 factors have been postulated or established in this group, chemically the individual members have little in common. Their structures vary greatly in chemical complexity and range from such a simple substance as nicotinamide to a very complex one such as riboflavin.

The fact that cereals play a large part in the nutrition of poultry makes the vitamin content of this class of feeds of basic importance. Eijkman used the chicken to prove the existence of antineuritic substance from rice polishings. Through the researches of Osborne, Mendel, Steenbock, and others, it was found that the above diet was materially remedied by a small addition of dried brewers yeast. Thus, it was then found that the beneficial factor in yeast was actually made up of 2 parts—1 of which was stable to heat and 1 destroyed by heat.

Since the food requirements of pigeons are simpler than those of chicks, for a time the pigeon largely replaced the chick in vitamin B studies. Later, the rat was used extensively in investigations concerning the dual nature of vitamin B. Later synthetic diets were introduced and this caused many complicated problems in vitamin assay. Purified rations are so constructed that one or more factors in addition to the one being investigated must be added in concentrated form. It is difficult to prepare these concentrates so that they are exceedingly low or devoid in the factor in question. Existence or nonexistence of some of the factors rest upon the purity of the preparation used.

Certain of the chemically identified members of the vitamin B-complex are closely associated with the oxidative processes of the body, which take place in a series of steps. Each one is dependent upon the preceding one and each is catalyzed by a specific enzyme; the entire process is held back when any step is interfered with by a deficiency of a particular enzyme. For example, thiamine, riboflavin, and nicotinic acid are indispensable parts of certain enzymes which are essential to this chain of interdependent chemical changes.

In recent years, chemical methods have been used to supplement biological and microbiological methods of assay with inherent advantages in some cases.

Hopkins, Osborne, and McCollum contributed much to the vitamin B-complex story. They worked largely with rats, noting the stunting of growth which ensues from a lack of these substances.

There are several B-vitamins each of which contributes to the growth of animals so that the growth tests in their cruder forms gave false results. Dutch scientists played an important role in the isolation and identification of thiamine. The method used by organic chemists in determining the structure of an unknown molecule is to tear it apart by progressive steps in fragments. When the fragments become small enough, the chemist can recognize them by comparing them with simple substances whose architecture is already known. Having recognized the ultimate fragments, they fit them together bit by bit to form primary fragments and, if possible, the original molecule. It is like the familiar jig-saw puzzle, except that one can never see the picture, let alone the pieces, except in the mind's eye. The payoff comes when the chemist constructs the product which possesses the properties of nature's own product. The isolation of thiamine required more than 20 yr of intensive work in many countries before the development of the structure was fully accomplished. Once the structure was known with certainty, a synthesis followed in a few months. The name "thiamine" implies that it is a sulfur-containing vitamin.

Nomenclature of vitamins is a whole lot easier today. For example, terms like "filtrate factor" and "animal protein factor" were common and in each case researchers tried to describe characteristics of the factor. "Filtrate factor" turned out to be pantothenic acid and since the active principle was not retained on the resorptive Fuller's earth, it was in the filtrate. Later on, it was called "chick antidermatitis factor" because of the symptoms involved.

Vitamins vary in the complexity of their chemical structure: niacin has a simple structure, and in the case of riboflavin or vitamin B_{12} concentrates the structures are complex. It is necessary to determine the values to crystallize the material. The chemist analyzes the crystals for composition and synthesizes it. If everything works all right, it is decided that this substance is the nutrient.

It was soon recognized that there was a multitude of essential substances in the B-complex which had to be isolated one by one, since they did not fit any particular chemical classification. Heat treatment destroys some of the B-complex. The part that is destroyed is called thermolabile vitamin B_1 or thiamine; that which was heat stable is called vitamin B_2 or riboflavin. Researchers first tried to identify nutrient factors and then find rich sources of it by making isolates. The successful isolation of thiamine in crystalline form came from rice polishings. This was accomplished by first adsorbing it on activated Fuller's earth or charcoal at pH 6.5. This served to separate the thiamine from the riboflavin and removed many other substances.

The chemical structures of many of these factors are known. The reason why there are many forms of a nutrient is as follows. Suppose the chemists

finally synthesize thiamine and it proved to be effective physiologically. The chemist is not content at this point because if industry is going to make it, they want to make it as cheaply as possible. If the formula is made up of 2 or 3 segments, perhaps just a segment will do the same thing as the whole formula. Then salts are made, and later, esters, so as to find which part can be made most economically. In the case of vitamin K, a dozen compounds have this activity because of modifications of the first one that they made. They have all been tested to show that they are active, but the one that is commercially used is the one that can be made at least cost.

In the case of thiamine, the crystalline derivatives of thiamine, isolated from yeast were found to behave as a cocarboxylate. The pyrophosphoric acid esters of the thiamine and its function are thought to be that of conversion of pyruvic acid to aldehyde and carbon dioxide. This shows where it fits into the biological scheme. It is part of an enzyme; if the body supplies the other part, it will function as the whole enzyme.

Thiamine.—The term "vitamine" was first used by Funk in 1912 for the dietary accessory substance previously found by Takaki and Eijkman to be necessary to prevent beriberi and polyneuritis in fowl. This substance was shown later to be vitamin B_1 or thiamine and was the first vitamin to be recognized biologically and isolated in crystalline form (1932).

The successful isolation was accomplished by adsorbing it on activated Fuller's earch at pH 6.5 which separated thiamine from riboflavin. After elution and further purification, crystallization of the vitamin occurred. Only about 5 gm of vitamin were obtained from 1 ton of rice polishings. Today, most of the thiamine is made synthetically. A reaction of thiamine now used as a chemical assay method is that resulting from treatment of the vitamin with alkaline potassium ferricyanide. The product is a yellow sulfur-containing pigment called thiochrome which shows a strong blue fluorescence, the basis for the assay of the vitamin. A derivative of thiamine from yeast behaves as a cocarboxylase, the pyrophosphoric acid ester of thiamine. This provides a link between vitamin B_1 and the enzymes. Thus, the vitamins may be considered to act biologically as part of an enzyme system.

Thiamine hydrochloride occurs in the form of a colorless, odorless crystal or as a crystalline powder very soluble in water, but only slightly soluble in alcohol. It is not oxidized and destroyed by exposure to air or light but is rendered inert by alkalies.

Beriberi, characterized by polyneuritis, is prevalent among Asiatic people who subsist on a diet composed mainly of polished rice. The body has little capacity for storage of antineuritic vitamins; a constant daily supply is necessary from foods or other sources such as yeast or vitamin extracts. Beriberi is called "kakke" in Japan.

It is easy to produce a thiamine deficiency. All is needed is to coop up birds and feed them for a month on polished rice. The birds become wholly uncoordinated and turn cartwheels or aimless floppings as if freshly decapitated. The fact that thiamine appears to play a role particularly in reference to nerve functions has been allowed to obscure somewhat its broader role to tissues in general. Fluid accumulates in the pericardium and lungs and death occurs after sudden exertion due to a heart failure. An excess of lactic and pyruvic acid in the brains of polyneuritic pigeons is responsible for the neuritic symptoms observed. This affects capacity to take up oxygen from the air. Carbohydrate metabolism is impaired.

Animals are unable to synthesize thiamine. Only the higher plants can make it, evidently in the leaves. Pathological changes in beriberi affect nearly all internal organs. Carbohydrate metabolism cannot go forward in any living cell without thiamine.

Function of Thiamine.—(1) Increases appetite, (2) promotes digestion, and (3) protects body from nerve disease.

Deficiency Symptoms of Thiamine.—(1) Polyneuritis (head drawn back due to paralysis of peripheral nerves), (2) impaired appetite and digestion, (3) constipation, (4) edema, and (5) starvation.

Sources of Thiamine.—Yeast, rice bran, wheat bran and middlings, most cereal grains, alfalfa meal, molasses, and tomatoes.

The average good poultry ration in which ground whole grains and cereal by-products such as wheat bran, wheat middlings, and alfalfa meal are used will carry from 2 to 3 times the requirement of vitamin B_1 for birds. In a practical sense, this vitamin is ignored because when a good average ration is fed, it automatically takes care of thiamine requirements.

Some substances contain an enzyme "thiaminase." This is found in certain types of fish and causes a paralysis. Cooking the fish destroys the thiaminase. Thiaminase is generally higher in the internal organs and viscera than in muscle tissue.

Riboflavin (Vitamin B_2).—After the division of the water-soluble group of vitamin B into B_1 and B_2 factions, it was shown that the B_2 group was also a mixture of substances. The original thermostable fraction from rice polishings and yeast contains vitamin B_2 or riboflavin in addition to other factors. Riboflavin actually was isolated from whey in 1933 as a water-soluble, yellow-green fluorescent substance previously found in milk and called lactochrome. An enzyme called the "yellow enzyme," a derivative of riboflavin, has been isolated from yeast. Riboflavin turned out to be a 6,7-dimethyl tetrahydro-pentylisoalloxine and is sensitive to light.

The "yellow enzyme" contains riboflavin as the phosphate in combina-

tion with protein which functions as the carrier. In order to function as a dehydrogenase (oxidase), the enzyme requires a coenzyme such as nicotinamide. Riboflavin occurs as a constituent of many other vitamins.

Functions of Riboflavin.—(1) Essential for growth, body maintenance, and health, (2) prevents curled-toe paralysis (enlarged sciatic nerve), and (3) needed for good hatchability.

Deficiency Symptoms of Riboflavin.—(1) Poor growth and feed efficiency, (2) curled-toe paralysis, and (3) poor hatchability.

Sources of Riboflavin.—Dried liver meal, dried whey, dried milk products, dried yeast, corn distillers dried products, and alfalfa meal.

Another of the B-complex vitamins, formerly known as vitamin B_2, is an orange-colored substance, slightly soluble in water and quite stable under normal storage conditions provided it is protected from light. It is essential to the utilization of both carbohydrates and proteins and plays a vital part in reproduction and maintaining the healthy condition of certain nerves. In practice, it is used in rations of breeding birds to insure good hatchability and in the rations of chicks to insure full growth and health. Riboflavin is found in milk and meat products. If it is exposed to black light, it fluoresces. For years, the poultry industry used high amounts of milk products to supply this factor. Such dairy products are too costly for this use today, but it was the only way then to get good growth and hatchability. Now, riboflavin is produced by the chemical industry to supplement rations more economically.

Industry has synthesized many of these factors at costs less than if they were isolated from a natural source. Rice polishings are very inexpensive in many parts of the world, but it is uneconomical to extract vitamins from it for feeding.

Characteristic of a riboflavin deficiency are toes and legs turning in. This was called the "curled-toe" factor for many years. If milk products or animal products are left out of the ration it may occur. Riboflavin is derived from the Latin word "flavus" meaning yellow color and "ribo" refers to the compound as a particular member of the class of compounds containing a special sugar called ribose.

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Pantothenic Acid.—Another B vitamin is pantothenic acid, a yellow oil-like compound soluble in water. It is known as an "antidermatitis factor" and it is quite stable under normal storage conditions. It helps insure a healthy skin, sound nervous system, good feathering, growth rate, and hatchability. Pantothenic acid is present in many feeds but during processing, it is bound up sometimes so that it is no longer utilizable by the birds. Some industries drum-dry their feedstuffs. If the temperature gets too high, pantothenic acid is bound and then its value is reduced as far as this particular nutrient is concerned.

Pantothenic acid was discovered in 1933, when it was found to stimulate the growth of yeast and prevent a specific dermatitis. The chemical nature of pantothenic acid was discovered in 1938. Because it had rather universal distribution in biological material, it was named pantothenic acid (P.A.) which means literally "from everywhere." It was found that yeast would grow into clusters like a bunch of grapes if given a decoction of yeast. The active ingredient in the decoction was subsequently shown to be pantothenic acid.

It occurs bound with protein in many types of animal tissues. Liver and kidney are rich in it and many molds and microorganisms produce the material. It is now synthesized but natural material is also used in the form of concentrates from rice bran and yeast.

The presence of peptidic bond in pantothenic acid explains why it is one of the most unstable members of the B-complex group of vitamins. The pH of the solution must be kept near neutrality as it is readily hydrolyzed under acid or alkaline conditions.

Pantothenic acid is particularly valuable for the very young and rapidly growing animal. Pantothenic acid deficiency is associated with dermatitis of the skin and graying of the hair or feathers, evidenced by a decreased concentration of melanin pigment in the hair apparatus. If a deficient rat is adrenalectomized, an almost complete reversal of the pigment loss occurs and the hair color is restored.

Chickens fed pantothenic acid-deficient diets have spinal cord lesions which account for the gradual loss of control of the legs and they are less susceptible to infection with pneumococcus. There is excellent evidence to show that P. A. is involved in the synthesis of antibodies and of great importance in maintaining the integrity of normal function of the adrenals. The essential block in the P.A. deficient animal, as far as the adrenal gland is concerned, is in its inability to synthesize an adequate supply of adrenal hormone. It is involved in the failure of the peripheral tissues to utilize the hormone. P.A. exists in tissues in so-called "bound form" and is a factor required for growth, for cellular integrity and function of the adrenal cortex. It serves as a key substance which makes possible the intricate transformation of numerous substances within the cell.

Function of Pantothenic Acid.—(1) Essential for growth, feather growth, healthy nerves, and (2) prevention of dermatitis.

Deficiency Symptoms of Pantothenic Acid.—(1) Poor growth, (2) ragged feather development, (3) sores in corners of mouth, scabs around eyes, and (4) scaly body and cracked foot pads.

Sources of Pantothenic Acid.—Dried liver and kidney meal, yeast, dried whey, dried milk products, wheat bran, rice bran, and alfalfa products.

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Biotin.—In 1934, Wisconsin researchers found that chicks are subject to "egg white" injury, later found to be due to an antivitamin, avidin, which rendered biotin unavailable. Egg white injury does not occur if the egg whites are cooked. In 1943, biotin was considered both an antiperosis and antidermatitis factor in turkeys. It was stated that practical turkey poult diets could be deficient in biotin. In 1942, it was found that microorganisms are capable of synthesizing biotin, therefore, intestinal microbes could be responsible for meeting all or part of the animal's requirement. Liver extract, dried yeast, and egg yolk afforded protection to animals. Biotin exists both in the free and bound forms and a substantial amount of the bound form is unavailable to poultry. Approximately half of the microbiologically assayed biotin in common feedstuffs is unavailable to chicks. Brewers dried yeast is beneficial not only due to the fact that it is a very good source of biotin, but also that it is a good antioxidant due to the high vitamin E content.

Cornell and Wisconsin researchers found that synthesis of biotin in the gastrointestinal tract of poultry is variable and undependable. Rancidification of fats and oils in the diet causes an indirect biotin deficiency. The nature of the carbohydrate sources also determines to some extent the availability of biotin. Dextrin favors intestinal biosynthesis of biotin while sucrose does not. Data obtained from microbiological assays do not represent the actual available biotin for the animal. Intestinal microbial biosynthesis may be significant but is affected by type of carbohydrate and drugs. The major biotin deficiency symptoms in poultry are dermatitis and perosis. Other symptoms are encrustations of the corners of the mouth, lesions in the foot pads, encrustation and closing of the eyelids, dryness and cracking of the skin, and bowing of the legs. Dermatitis of the foot pad is the earliest sign of a biotin deficiency. Low levels of penicillin and terramycin in the ration of turkey poults reduces the biotin requirement. Antibiotics reduce the number of intestinal microorganisms which compete with the host for biotin. A biotin deficiency tends to induce a vitamin B_{12} deficiency.

Biotin is readily soluble in hot water, sparingly soluble in cold water, stable to heat, and labile to oxidizing agents, strong acids and alkalies. It combines with avidin, a glycoprotein of raw egg whites to form a stable complex which is not broken down by proteolytic digestion and thus nonabsorbable and nutritionally unavailable. Biotin acts as a coenzyme involved in carboxylation and decarboxylation. It is synthesized in the intestinal tract in sufficient quantities to render an exogenous source unnecessary.

Biotin deficiency can be produced by forcing birds to consume considerable raw egg white, in which case there develops a scaly dermatitis, extreme lassitude, anorexia, and a slight anemia. These symptoms respond promptly to the administration of biotin. Meats of organs are excellent sources of biotin; peanuts and egg yolk are good sources.

Biotin is stable under normal storage conditions and essential for good growth and hatchability, as well as the prevention of slipped tendons and dermatitis. In chicks deficient in biotin, there is an encrustation due to the cracking of the skin, particularly along the bottom of the feet. Raw egg white contains an antagonist which destroys biotin. Cooking eggs destroys the antagonist but drying at low temperatures does not.

In 1942, Jukes demonstrated that chicks fed a purified diet containing all known nutrients, except biotin exhibited perosis in addition to poor growth and a scaly dermatitis. Injection of crystalline biotin completely prevented the dermatitis and improved growth.

Much of the bound biotin is unavailable to chicks and turkeys. Approximately one-half of the microbiologically determined biotin in a feedstuff is biologically unavailable to poultry. Biotin is synthesized in the intestinal

tract but produces undependable amounts for the nutrition of chicks and poults.

Biotin is inactivated in rancidifying diets either by fats or by pure ethyl linoleate. There is some biotin carryover from the breeder diet which affects the early nutrition of the poult. Evidence is accumulating that some practical turkey rations are deficient in biotin. Reports of this deficiency have come from western Canada and many scattered parts of the United States. Observed are dermatitis on the bottom of the feet, reduced growth rate, and general unthriftiness. Although synthesis of biotin by microorganisms in the digestive tract exists, drugs and other feed additives are suspected of playing some role in affecting that synthesis. Pure crystalline biotin and biotin 1% in finely divided powder are available for feeding. Since the requirements of turkeys for biotin are higher than for chickens it is important to feed chickens the higher turkey levels.

TABLE 14.3

POULTRY BIOTIN REQUIREMENTS

Species	Biotin Requirement
Chicks	2 mcg/day
Poults & breeders	0.300 -0.350 mg/kg diet
Poults	0.250 mg/kg diet
Turkey breeders	0.200 mg/kg diet

Function of Biotin.—(1) Prevents a typical dermatitis, and (2) poor growth.

Deficiency Symptoms of Biotin.—(1) Resembles those of pantothenic acid deficiency, except with biotin deficiency, the dermatosis appears first on the feet, whereas with pantothenic acid deficiency, they appear first on the head.

Sources of Biotin.—(1) Liver extract, dried yeast, and egg yolk.

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Folic Acid (Pteroylglutamic Acid).—The research which culminated in the synthesis of this vitamin is one of the most exciting chapters of nutrition. It started in 1938 and ended with a synthesis of the new vitamin in 1945 by the Lederle Laboratories Division of the American Cyanamid Co.

Folic acid is a water-soluble, yellow crystalline compound—labile to heat in acid solution and to sunlight. The vitamin is present in many foods, especially green leaves, liver, and yeast. Its molecule contains pyrimidine and pyrazine rings joined together to form a pteridine grouping with folinic acid; it frequently occurs as conjugates with glutamic acid.

Its relative abundance in leafy materials prompted the name folic acid from the Latin "folium" meaning leaf. It was isolated in 1943 and synthesized in 1945. Chemically it is pteroylglutamic acid (PGA). One molecule of folic acid consists of three substances joined together. The first is the yellow pigment which imparts the color to folic acid and is called pterin. It belongs to the class of color substances found in the wings of butterflies. The second substance is para-aminobenzoic acid, a growth factor for many bacteria. A third substance is glutamic acid, an amino acid occurring in large amounts in cereals. The three components do not produce the vitamin effect of folic acid if fed separately. The intact molecule alone can serve as the vitamin.

Folic acid produces a hemopoietic (blood forming) response. Growth, egg quality, hatchability, oviduct growth, integrity of hemoglobin formation, resistance to infection, feather growth and pigmentation depend to a degree on an adequate supply of folic acid. A deficiency of folic acid in the diet is characterized by macrocytic anemia. Folic acid is essential for life.

For some time, researchers had evidence that chicks required a dietary factor for growth which was not identical with the then known vitamins. This factor was extracted from yeast, spinach, and other products and was called at various times factor U, vitamin B_3, norite eluate factor, L-casei factor, and folic acid. Although substantial amounts of folic acid are present in leafy materials, some nonleafy sources such as mushrooms, yeast, liver, and kidney also contain it.

The grains, especially corn, fishmeal and meat scraps are poor sources of this vitamin. Soybean oil meal is a fairly good source and high quality alfalfa meal is one of the richest sources. The factor is also present in middlings and wheat bran.

A deficiency of folic acid in poultry causes a spastic type of cervical paralysis and mortality runs very high. Requirement for poults is at least twice that of chicks. There are several forms of folic acid all exhibiting similar nutritional activity for animals. Since it is transmitted through the egg to progeny, chicks from folic acid-deficient hens are of poor quality, since they are weak, crippled, and have a high mortality rate. Their down

fails to fluff out normally. The anemia is distinguished by abnormally shaped (microcytic) red blood cells which are less fragile than normal. There is a reduction in the number of red blood cells and the hemoglobin content is increased.

Like many other feed factors, folic acid has numerous and complex interrelationships with other nutrients. The debilitating changes associated with anemia account for the wide variety of symptoms of a folic acid deficiency. These include pitted and weak egg shells, impaired semen production, reduced growth, neck paralysis, disturbed feathering, diarrhea, rubbery legs, general weakness, deranged endocrine function, and mortality. In the field, when hard to explain problems arise from inferior performance, folic acid should not be overlooked in treatment.

Folic acid and vitamin B_{12} are concerned with the metabolism of a chemical fragment which, in turn, can form methyl groups used in the formation of choline and methionine. The methionine requirement of the chicks is increased with diets partially deficient in folic acid or vitamin B_{12}.

Folic acid deficient chicks develop depigmentation in the wing and tail feathers, although most of the feathers are affected in some way. They have a lowered natural resistance to *Escaridia galli* infection. They develop perosis after being fed a diet deficient in folic acid but adequate in choline, biotin, and manganese.

Goslings fed a diet deficient in folic acid up to two weeks of age suffer cervical paralysis which is cured by intramuscular folic acid injections. It causes anemia in ducks and decreased weight gains result as well as pathological changes in the liver and pancreas. Folic acid is available to feed manufacturers as a feed supplement with a guaranteed level of folic acid. This supplement also contains some sodium chloride and diatomaceous earth.

Function of Folic Acid.—(1) Synthesis of purine and pyrimidine for formation of muscle proteins, and (2) necessary for normal growth, blood building, feather development and egg production.

Deficiency Symptoms of Folic Acid.—(1) Macrocytic megaloblastic anemia, (2) lowered blood cell count and hemoglobin content, and (3) paralysis in turkeys, chickens, and geese.

Source of Folic Acid.—(1) Leafy materials, liver, yeast, and synthetic.

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Choline, Betaine, Lipotropic Agents.—Choline, a powerful base, is more of a macro than a micro nutrient, yet it is usually discussed with the vitamins. Choline is synthesized in birds but not always adequately. It is not a structural part of any recognized cofactor active in enzyme reactions but a part of the phospholipid, lecithin. In 1932, Best showed that choline played a vital role in nutrition by prevention of fatty livers in rats. It occurs in all living cells and assists in the movement and utilization of fats. As a component of phospholipids, it serves as a labile methyl donor in the body.

Choline chloride as a crystalline salt is very hygroscopic so it is marketed as a dry supplement guaranteed to contain specified amounts of choline or as a 70% liquid. It is soluble in water and alcohol but not in ether. It is needed for growth, egg production, hatchability, and kidney function. Grains are low in choline; animal products, soybean and cottonseed meals are fair to good sources.

Deficiency symptoms include a leg disorder, fatty livers, and reduction in red blood cell count. In poultry, it is a specific for preventing a type of perosis when manganese is present and plays a methylation role in which the choline is oxidized to betaine. Today's broiler rations contain added fat which increases the requirement for added choline. Since 1943, synthetic choline has been used to supplement that present naturally in feedstuffs. It is produced from natural gas and supplied as a chloride which is 87% choline.

Poults have a higher requirement for choline than chicks due to their more rapid growth. Betaine or methionine cannot completely replace choline. The level of methionine in the ration is important in choline requirements. The former furnishes methyl groups needed for choline synthesis. If choline is adequate, methionine is available for other purposes since methionine is usually the first limiting amino acid in poultry rations.

Choline is assayed as a precipitate with Reinecke's salt which is dissolved in acetone and determined spectrophotometrically at 5200 Å. A microbiological procedure utilizes a mutant of the mold *Neurospora crassa* which requires choline for growth. Of great practical interest is the relationship of methionine, cystine, and betaine to choline. Cystine aggravates or in-

creases choline-deficiency symptoms, while under certain conditions, a liberal intake of methionine or betaine alleviates them.

Choline can be produced in the body of laying hens from labile methyl groups, although as stated, chicks and poults have only a limited ability in this respect. Because laying hens can perform this synthesis, they are able to dispense with choline if a large supply of some other methylating substance such as methionine is furnished in the diet. Choline corrects such diets but betaine and additional methionine are ineffective. Methionine cannot be replaced by other substances in fat metabolism. However, homocystine can substitute for methionine providing a methylating agent such as choline or betaine is included in the diet.

Choline markedly increases the growth of chicks on diets deficient in methionine but containing added homocystine. Since methionine is expensive, choline should be added to the ration. This conserves methionine for its essential function in building new proteins and prevents it from being drained away to supply labile methyl groups which can be supplied more economically from choline. Choline is considered one of the B-vitamins, although it does not qualify with respect to certain characteristics. It is essential to the proper utilization of fat. Choline is particularly important in the diets of young stock because it is concerned in the production of new body cells and in bone development. Choline helps prevent some slipped tendons which are not improved with manganese, particularly in poults. However, some twisted legs occur in birds, particularly at hatching time, that are not due to lack of either manganese or choline. Choline was first isolated from the bile of chickens in 1849, but its value in nutrition was recognized only in the 1930's. It is a component of lecithin phospholipids which are widely distributed in nature and found in nearly all animal tissues and in many plants. Good sources of lecithin are egg yolk, yeast, liver, heart, kidney, and certain oil-bearing seeds such as soybean oil. Lecithin is fat-like, high in energy, and has many uses ranging from food products to an anti-knock compound in gasoline.

Choline is termed a lipotropic agent, which means it has an affinity for fats and oils as well as water. It facilitates the transportation of fats in the blood stream. It is a rather hygroscopic substance: if the solid is left overnight in an open bottle, it will become fluid by morning. It is usually used in feeds as the chloride salt or the xanthate which is not hygroscopic. The most popular feed additive is supplied as a 70% solution in water which is what develops if it is exposed to the air or 25% choline chloride in a dry carrier.

Both manganese and choline prevent perosis which occurs in turkeys and chickens and is characterized by short thigh bones, deformation and dislocation of the hock joint, and slipping of the tendons at the hock joints.

Choline is an excellent methylating agent containing three biologically available methyl groups. Betaine and methionine are also methylating agents. Betaine is only one-third as effective as choline in the prevention of deficiency conditions. There is an interrelationship between choline, betaine, and methionine. However, they are not quantitatively equivalent. Choline, plus some other vitamins was usually recommended. Much choline was used even though it was not usually effective.

Lipotropic compounds like choline distribute fat better in the body. They are most effective when used with animals from which pancreases are removed; with normal animals it does not work as well.

Choline is a strong base and crystallizes with difficulty. It is soluble in water, absolute alcohol, and ether. When choline decomposes, it forms ethylene glycol, polyethylene glycol, and trimethylamine.

In summary the intact choline molecule is a structural part of phospholipids and acetylcholine which aids in the transmission of nerve impulses. It is used for perosis in chicks and turkeys, and for hemorrhagic kidneys in pigs, rats, and mice. It is not replaced by betaine or methionine for certain functions. Choline furnishes labile methyl groups to spare methionine and for other metabolic processes such as detoxification. The amount of choline that is obtained from normal feed ingredients is just borderline, so it is best to add some to the feed, since it will be helpful in many cases and is relatively low in cost. It is widely distributed in the plant world, being found in greatest concentrations in young growing leaves, i.e., the young leaves of the sugar beet.

To convert choline to choline chloride, multiply by 1.152; choline chloride to choline, multiply by 0.8679.

Function of Choline.—(1) A structural part of phospholipids and acetylcholine which aids transmission of nerve impulses, (2) normal fat metabolism, and (3) furnishes labile methyl groups to spare methionine.

Deficiency Symptoms of Choline.—(1) Perosis or slipped tendon, fatty livers, and (2) decreased egg production.

Source of Choline.—(1) Liver meal, wheat germ, and soybeans. However, feeds are usually supplemented with the synthetic vitamin.

Depancreatized dogs kept alive by insulin develop large yellowish livers due to excessive deposition of fat. Raw pancreas or lecithin is effective in preventing the fatty livers. In 1924, Canadian researchers found that the constituent in crude lecithin responsible for its lipotropic activity was choline and to some extent betaine.

Casein and egg white also possess distinct lipotropic effects largely due to their content of amino acid and methionine.

As to mode of action, choline combines readily with the neutral fat and phosphoric acid to form phospholipids which are more soluble in body

fluids than neutral fats. Lipotropic effect of betaine and methionine is due to their ability to donate methyl groups for the synthesis of choline. When young animals are deprived of a dietary source of methionine, growth ceases. As stated, animals grow when fed methionine-deficient diets which contain homocystine, together with a source of labile methyl groups. By the process of transmethylation, they take methyl groups from betaine or other methyl donors and transfer them to homocystine to form methionine. Lipocaic is a substance, probably a hormone, found in the pancreas which prevents deposition of lipids in the liver.

Betaine.—Betaine is a naturally occurring amino acid derivative which enhances the value of the ration in several important ways. It furnishes methyl groups which play an important part in protein metabolism. Betaine is obtained from the beet sugar industry. Its chemical composition and biological activity are related to choline and methionine. It spares the choline and methionine for full use in the functions for which they are irreplaceable. Betaine, choline, and methionine all have a common function in being methyl donors but also have special functions of their own. They are present in certain wheat products, particularly wheat bran middlings and alfalfa; in many instances it is more economical to add betaine to formula feeds.

Betaine is a colorless deliquescent, crystalline substance and may be considered as completely methylated glycine. It is very soluble in water and alcohol but only slightly soluble in ether. Solutions of betaine in water are neutral. Betaine is the oxidized or acid form of choline. Betaine cannot replace methionine in the formation of protein. Thus, betaine has a more restricted function in nutrition than that of choline or methionine.

When the chick's ration contains insufficient amounts of choline and betaine, a considerable demand may be made on methionine for these methyl groups. Since the use of methionine is nutritionally inefficient, it is more economical to supply other methylating compounds, such as choline or betaine.

Betaine is available in large quantities from natural sources. It was first isolated from the plant *Lycium barbarum*, a member of the night-shade family in 1864. Later, it was found in relative abundance in the sugar beet plant. It is found in greatest concentration in the young, growing leaves. Little is found in the seeds or roots (except sugar beets). Its presence in marine animals, especially mussels, and in kidneys and liver of cattle and swine has long been known.

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Niacin.—Niacin cures pellagra in humans and black tongue in dogs and is needed by all animals. It is a white crystalline compound soluble in hot water, nonhygroscopic, and can be autoclaved with no loss of activity. It is also stable to light, acids, and alkalies. Plant tissues contain the vitamin in the form of the acid; animal tissues, in the form of the amide. Both forms are physiologically active. Commercial supplies are now made synthetically. Niacin was isolated in 1912 from rice by Suzuki. It is essential to the utilization of carbohydrates.

The germ theory of disease dominated the thinking of medical science during the middle of the last century through the spectacular researches of Pasteur, Koch, Lister, and others. The discovery of vitamins shortly after the beginning of the present century introduced an entirely new concept—that disease could result from the absence or insufficiency of specific factors in food. Perhaps the most dramatic example of this revolutionary concept was revealed in the case of pellagra, a degenerative disease which was particularly prevalent among the poor.

The name "pellagra" comes from the Italian "pelle" skin, and "agra" rough. As of 1914, it was thought to be caused by a toxic substance in corn or by infection from an unknown microorganism. The U.S. Public Health Service assigned Goldberger and associates to the problem in 1914. They showed promptly that it was impossible to transmit the disease by innoculating skin scales, secretions, and excretions from persons severely ill with the disease into healthy volunteers. Using orphanages and prisons, it was shown that pellagra could be prevented by diet alone. The diet of the poor consisted mainly of biscuits, fried mush, corn grits, brown gravy, syrup, black coffee, sugar, corn bread, cabbage, sweet potatoes, rice, and collards. Restricted to these foods, people developed skin lesions in five months. Where people consumed animal products in addition, they did not succumb

to the disease. Experimental work was conducted also on monkeys, dogs, rats, chickens, and other animals.

Chemists at the University of Wisconsin (Elvehjem, Madden, Strong and Wooley) worked with concentrates from liver and also nicotinic acid. This pure chemical previously had been tried as a beriberi preventative without success. It was found that nicotinic acid prevented black tongue in dogs. The importance of nicotinic acid (niacin) in the treatment of human pellagra was soon confirmed by clinical studies. Thus, ended an intensely interesting chapter in the story of nutrition.

Nicotinic acid, in the form of the amide, is now known to be an integral part of two enzyme systems—coenzyme I (diphosphopyridine nucleotide), and coenzyme II (triphosphopyridine nucleotide). These coenzymes are intimately involved in intercellular oxidation and metabolism of protein and carbohydrates. Because of the frequent erroneous association in the popular mind of the vitamin nicotinic acid with the alkaloid, nicotine of tobacco, the name niacin has been used for this vitamin since 1942.

Turkeys require relatively high levels of both vitamin E and niacin for prevention of enlarged hock disorders. Dried brewers yeast prevents this disorder due to its high level of niacin and the fact that it contains highly potent antioxidant properties that protect vitamin E in the ration. In mammalian tissues, niacin can be synthesized from the amino acid tryptophan; this does not take place in the absence of pyridoxin.

The niacin content of a feed can no longer be considered without taking into account its tryptophan content as well. Corn is a poor source of niacin and also lacks adequate tryptophan which could be used as a precursor of niacin. Milk is a relatively poor source of niacin but it is pellagra preventive because of its more than adequate tryptophan content.

Function of Niacin.—(1) Metabolite in enzyme systems associated with intercellular oxidation and metabolic rate, and (2) contributes to growth and increased feed efficiency.

Deficiency Symptoms of Niacin.—(1) Inflamed mouth (dark red lining), retarded growth, poor appetite, ragged feather development, and scaly skin.

Sources of Niacin.—(1) Liver, meat, fish, yeast, wheat germ, alfalfa, and fish solubles.

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Vitamin B_{12} (Cyanocobalamin).—Vitamin B_{12} was recognized for over a quarter of a century before it was separated from liver as a major part of the animal protein factor (APF). It has since taken the more dignified name cyanocobalamin. It is a water-soluble, red, crystalline compound which is labile to acids, alkalies, and light.

Vitamin B_{12} plays a role in the transfer of single carbon intermediates, primarily methyl groups, for example, the synthesis of choline from methionine, the formation of serine from glycine, and methionine from homocystine. Vitamin B_{12} also takes part in the formation of pyrimidine bases, in purine metabolism, and in the metabolism of nervous tissue. It is very poorly absorbed from the gastrointestinal tract unless a heat labile protein, the intrinsic factor, is also present. This factor is secreted by normal, healthy stomach mucosa, and facilitates the transfer of the vitamin across the mucosal membrane.

Courtesy of Poultry Branch, U.S. Dept. Agr., Beltsville, Md.

FIG. 14.1. RHODE ISLAND RED CHICKS HATCHED FROM EGGS LAID BY HENS FED AN ALL-PLANT PROTEIN LAYER FEED DEVOID OF VITAMIN B_{12}

The larger bird was hatched from an egg injected with one-millionth of a gm of vitamin B_{12} at 10 days of incubation. The smaller bird came from an untreated egg. Both chicks were fed a vitamin B_{12} deficient diet from hatch through 5 weeks of age.

Vitamin B_{12} is found almost exclusively in feeds of animal origin. The original source of the vitamin is probably bacterial fermentation in the intestinal tract of animals, particularly in the rumen of herbivora. Poultry do not derive enough vitamin B_{12} from endogenous bacterial synthesis and thus are dependent on the supply of the preformed vitamin in the diet. Liver and kidneys are excellent sources of vitamin B_{12}. Muscle meat and

fish supply it in moderate amounts but most materials are very poor sources. The kidney, liver and pancreas have the ability to store appreciable quantities of vitamin B_{12}.

In addition to that which comes from APF supplements, fermentation residues, which produce antibiotics, such as streptomycin, penicillin, aureomycin, and terramycin, contain significant quantities of the vitamin. In fact, some of the difficulties in the early research on this vitamin was due to the presence of residual amounts of antibiotics in some of the supplements. At first, the importance of the carryover of vitamin B_{12} from the dam to the egg and hence to the hatched chick was not fully appreciated. Increased protein in the ration increases the need for vitamin B_{12}. Thus, a balance of protein and energy is necessary to get the best response from vitamin B_{12}.

Vitamin B_{12} is found naturally in fishmeal, fish scraps, and meat scraps, but there is a definite need for supplementation in most practical rations. Deep litter can supply some vitamin B_{12} for breeders but the amount is variable and cannot be depended upon.

Vitamin B_{12} is the first cobalt-containing substance which has been found to be essential for life and the only vitamin that contains the essential mineral element. Eggs from the same hens show individual differences in vitamin B_{12} content. Addition of high levels of fat to the ration markedly depresses chick growth unless the vitamin B_{12} level is increased. Vitamin B_{12} is markedly increased in the liver storage of vitamin A from the carotene.

Function of Vitamin B_{12}.—(1) Promotes growth and high hatchability, (2) antipernicious anemia factor in humans, and (3) protein synthesis.

Deficiency Symptoms of Vitamin B_{12}.—(1) Anemia, (2) some nervous degeneration, and (3) fatty livers, hearts, and kidneys.

Sources of Vitamin B_{12}.—(1) Liver, meat scraps, fishmeals and solubles, and animal proteins in general, and (2) fermentation residues.

This nutrient was isolated about simultaneously by biochemists at Merck Co. in the United States and Glaxo Laboratories in England, and contains both cobalt and phosphorus. It is very effective in the treatment of pernicious anemia in humans, particularly in conjunction with folic acid, and stimulates growth in chicks when used at very low levels. Vitamin B_{12} turned out to be a part of the animal protein factor but there are still other factors in APF which have not yet been identified.

The fact has long been recognized that differences exist between protein supplements of an animal and vegetable origin. These differences were usually attributed to a more complete essential amino acid pattern in animal proteins. For example, Canadian workers in 1935 observed that crude casein provided a factor for growth of chicks and U.S. Dept. Agr.

workers found that the hatchability of eggs produced by hens on an all vegetable basal diets was very poor. Fish products carried a factor which improved the rate of growth of chickens fed vegetable protein diets. With hens fed a diet made principally of corn-soybean meal with appropriate mineral and vitamin supplements, hatchability of eggs was very poor but if the hens were kept on built-up litter eggs hatched better. Until World War II, it was common to formulate a ration with half of the protein from animal sources. Since then, protein has come mostly from vegetable sources.

Vitamin B_{12} is particularly important for growth and hatchability and is required in greater proportion in rations of breeding stock and chicks under eight weeks of age than in the diets of growers or commercial layers.

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Vitamin B_6 (Pyridoxin).—In 1934, Gyorgy proved the existence of an essential nutrient factor which was called vitamin B_6 and later pyridoxin, and was synthesized in 1939. It occurs naturally in free and conjugated, or bound forms, and is widely distributed over the entire animal and plant world. It occurs in combination with protein and starch. Heat or enzymatic hydrolysis is necessary to bring it into the free state so it can be separated and obtained in crystalline form. Pyridoxin is made synthetically today for commercial feeds.

It exerts its biological activity by being converted into phosphorylated compounds, principally pyridoxal-5-phosphate, the coenzyme of a wide variety of specific catalytic proteins. It functions in the metabolism of tryptophan. Interesting relationships between pyridoxin and fatty acid metabolism have been shown. It also serves as a coenzyme for actions involving amino acids.

The vitamin B_6 group of vitamins includes pyridoxin, pyridoxal, pyridoxamine, and the respective phosphate esters. Principal vitamin activity resides in the enzymatically-active form pyridoxal-5-phosphate. Deficiency symptoms are great excitability and seizures, disorders of the skin, alterations in fatty acid metabolism, including the synthesis of es-

sential fatty acids, anemia, impaired antibody formation, and atherosclerosis. It participates in a wide variety of enzyme systems, particularly related to the transformation and utilization of amino acids. The most important reactions are decarboxylation and transamination. It is destroyed by excessive heating.

Function of Pyridoxin.—(1) Pyridoxin (vitamine B_6) is essential for the growth of chicks.

Deficiency Symptoms of Pyridoxin.—(1) Slow growth, depressed appetite, followed in some cases by spasmodic convulsions and death.

Sources of Pyridoxin.—(1) Grain, milk products, egg yolk, yeast, and rice polishings. Vitamin B_6 or pyridoxin is another B-complex vitamin. It is a colorless, crystalline compound, soluble in water and stable during artificial storage if it is protected from light. It is essential to the utilization of proteins and necessary to maintain normal appetite.

Almost any feed additive can cause trouble if used at too high a level. Usually there is a margin of safety of at least 1,000% but in some instances it is not that high.

Vitamin C

Vitamin C or ascorbic acid is not essential for poultry as it is for most other animals.

INOSITOL

Inositol occurs naturally in both plants and animals and is a factor related to the metabolism of fat and cholesterol. It was discovered in 1850 by Scherer who isolated it from animal muscle tissue and named it for the Greek word "Inos" meaning muscle. It is one of eight isomers and may be likened to glucose in which the aldehyde group of the sugar has been changed to a secondary alcohol group.

The phosphoric acid esters of inositol are the most common inositol derivatives. The hexaphosphate ester is called phytic acid, most heavily concentrated in seeds and grains where it accounts for 86% of the total phosphorus. Inositol in soybeans represents 40% of the total phosphorus. Inositol is found in many of the vital organs of the animal body, being richest in heart, brain, stomach, kidney, spleen, and liver, chiefly in the cytoplasm of the cell.

Inositol is a factor of primary importance for the growth of yeast and is generally accepted as a member of the vitamin B-complex. In chickens, inositol increases the growth rate of young chicks but it is also synthesized by chicks maintained on normal diets. The absence of inositol in turkey rations slows growth of the poults and causes anemic conditions. The possibility of intestinal synthesis and the extensive occurrence of inositol

in foods make it extremely difficult to demonstrate an inositol deficiency. Inositol is one of the substances which are primarily important in the utilization of fat in the body. These substances, known as lipotropic agents, assist in preventing the deposition or in hastening the removal of excessive amounts of fats from body tissues.

Unidentified Growth Factors (UGF)

INTRODUCTION

At one time, all of the now well-known vitamins were unidentified nutrients and recognized only by their effects on growth, performance, and health of poultry. Once a new nutrient was identified, questions were raised as to whether or not all required nutrients were known. Factors for which scientists are still searching are those needed chiefly for economical performance. In a favorable environment birds may grow moderately well without addition of any new UGF sources.

UGF are difficult to study for the following circumstances: (1) in most cases, relatively small differences in growth rate and feed conversion are now obtained; (2) it is necessary to compare the results of many and large groups of chicks, preferably of a single sex; (3) there is usually more response from cockerels than pullets; and (4) various types of stress factors also apparently affect the UGF requirement. Some researchers prefer to make UGF studies with turkeys, a faster growing animal with more critical nutritional requirements.

ANIMAL PROTEIN FACTOR

In 1933, the US Dept of Agr. researchers found that animal protein concentrates contained a factor required for normal hatchability of eggs. Fish by-products, meat meal, meat scraps, liver, dried skimmilk, dried buttermilk, and green grass supply the factor required for normal reproduction and optimum growth. The hatchability factor required by hens and the growth factor required by chicks are identical since they occur in the same materials and there is a carryover from hens to chicks. Plant proteins contain varied amounts of UGF.

Since the isolation of vitamin B_{12} by Merck Laboratories in 1948, many investigators noted that a variety of natural materials are capable of stimulating growth in poultry when added to diets adequate in all known essential nutrients. Although evidence for the biological activity of several organic compounds and minerals not previously known to be required by the chick has been made recently, it is still necessary to use crude sources of UFG in composing practical rations for chicks and breeders.

Hens reared on built-up litter and fed simple rations lay eggs which hatch well. With the discovery of vitamin B_{12}, response to UGF became more evident. Vitamin B_{12} is only a part of the animal protein factor but is used in place of some animal protein in some rations. Chickens

grow on so-called "purified" rations composed of a carbohydrate such as glucose, a protein such as casein, pure vitamins, and crystalline salts. However, if casein is replaced with its essential amino acids, growth is inferior. This suggests that crude casein contains unknown growth factor(s). Furthermore, it is possible to formulate a diet of special feedstuffs which does not support satisfactory rate of growth unless supplemented with some other feedstuffs. This strongly suggests unknown growth factors but is not proof. It may result from an interrelationship between known nutrients or from the destruction of the nutrient in the basal diet. Undoubtedly, the time will come when all factors can be supplied in pure form. Before that time, new crude sources will be developed. For the sake of insurance, high quality poultry mashes ought to contain some dried whey and alfalfa meal.

Although it is not known how many UGF exist, there is a much better understanding of these factors than previously. It is known, for example, that there are some sort of interrelationships existing between some of them. Appropriate combinations of several UGF products in poultry grower and breeder rations offer most promise of giving satisfactory growth and hatchability.

EXISTENCE OF OTHER UNKNOWN FACTORS

As early as 1940, Cornell researchers presented evidence for a hitherto unidentified chick growth factor in dried brewers' yeast which they designated factor "S." Purdue scientists reported the presence of this factor in crude commercial casein, dried skimmilk, fish solubles, dried whey, and later, distillers' dried solubles, possibly due to its yeast content. Practical-type basal rations were used for the most part in experiments but in view of the difficulties involved purified ingredients were gradually adopted. It was necessary to supplement the purified basal ration with dried liver in order to obtain optimum growth.

Later, these researchers fed a group of chicks the ash of a mixture of five sources of unidentified growth factors. Marked growth increase (approximately one-half again as great as the unashed material) was promoted by the ash. It is evident, therefore, that unknown organic factor(s) and also unidentified mineral element(s) are required for maximum chick growth.

The question as to how many unknown factors still exist cannot be answered until each is isolated in crystalline form and when added to a synthetic diet consisting of pure nutrients, does not give further improvements. Experiments have shown that the "fish solubles" factor is contained in fish solubles and meal, meat scraps, dried whey and other milk products, as well as penicillin mycelium meal. The "fermentation solubles" factor is found in dried corn distillers' solubles, molasses, liver meal,

brewers' dried yeast, fish solubles, and soybean meal. The "grass juice" factor is found in fresh forage juice, liver meal, brewers' dried yeast, dried whey, dried skimmilk, dried buttermilk, soybean meal, and fermentation dried solubles. Unidentified mineral factors are found in distillers' dried solubles, fish solubles, feather meal, soybean oilmeal, brewers' dried yeast, and dried whey. The protein factor is found in soybean meal, peanut oilmeal, casein, and gelatin. Turkey poults have an even greater requirement for unidentified factors than young chicks.

The existence of unidentified nutrients necessary for optimum growth efficiency and reproduction in poultry presents a problem of great economical importance to feed manufacturers, since in most instances these factors are found in the ingredients which are relatively costly because of difficulties encountered in their manufacture. For economical feed manufacture, therefore, as low a level as possible of unidentified growth factors is used.

NUMBER OF GROWTH FACTORS

After many years of research there is still a difference of opinion of how many growth factors there are. In practical feed formulation it is not necessary to add more than 2½ to 3% of unidentified growth factor sources, but it is a common practice to use more than 1 source. There is no test available for the evaluation of UGF sources, except a chick or poult feeding test.

In 1944, it was recognized that in addition to important quantities of calcium, phosphorus, riboflavin, and certain essential amino acids, animal protein concentrates contain unidentified factor(s) necessary for rapid growth in chicks and normal hatchability. This unknown factor was named the "animal protein factor" (APF) because of its common occurrence in fishmeal, meat scraps, dried skimmilk, liver meal, and crab meal. This vitamin is required for normal hatchability and constitutes the most important part of the animal protein factor. However, research work revealed that still other unidentified factor(s) in addition to vitamin B_{12} are involved in animal protein and are needed for rapid growth and good hatchability.

The name, animal protein factor, is confusing because it suggests that the material is protein and this is not the case . . . it is actually vitamin in nature. As stated, the name originated because the vitamin occurred in very close association with certain animal protein supplements.

There is a decided difference in the ability of chicks to live depending upon the diet of the hens which laid the eggs from which they were hatched. When hens are fed diets principally of corn and soybean meal with appropriate mineral and vitamin supplements, hatchability of the eggs is poor and chicks that hatch from those eggs are small and weak and mortal-

ity is high. However, when a source of animal protein is added to the diet of the breeder hens, hatchability is improved very decidedly and the chicks are strong. Egg production of these hens is not affected but hatchability drops to a very low level when there is no source of APF present.

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Minerals

MAJOR MINERALS

Calcium and Phosphorus

If you analyzed poultry tissue or eggs, about every chemical element would be found—some essential; others not. By essential, is meant not only for growth but other aspects of the performance of the birds as well. Certain essential elements, present in larger amounts than others, are called "major" or macronutrients. Some needed in very small amounts are termed "trace" minerals. The mineral part is inorganic and remains after ashing the product. Those needed in substantial amounts are calcium, phosphorus, magnesium, sodium, potassium, and sulfur. Examples of those needed in very small or trace amounts are copper, cobalt, iodine, manganese, zinc, fluorine, molybdenum, and selenium. There are others that are there in trace amounts, but are not essential to the performance of birds—aluminum, arsenic, nickel, and silica. If you withdraw the latter from the feed, animals seem to do just as well. Inorganic nutrients or minerals should not be treated as single ingredients. They are interrelated just as are the vitamins and proteins. For example, calcium and phosphorus should be in definite relationship in the feed for formation of bone in the bird.

Calcium and magnesium are necessary for nerve cell function. Iron, copper, and cobalt are interrelated with vitamin B_{12} in blood formation. Iodine is an essential constituent of the thyroid hormone. Zinc, molybdenum, and manganese serve as essential parts of a number of enzymes. All of these essential nutrients are needed by the body and all must be derived from the diet. Three minerals that are most likely to be critical in feeds are calcium, iron, and iodine.

Calcium and phosphorus are vitally concerned with each other in feeds since they are closely interrelated. A deficiency or an overabundance of one may interfere with the proper utilization of the other. Calcium and phosphorus must be in the feed in sufficient amounts and the elements must be present in forms that are efficiently digested and utilized. There is usually little concern with calcium in this regard. Calcium is seldom found to be deficient and there is no problem with respect to its biological value. Limestone, pure calcium carbonate, calcium sulfate and calcium gluconate, bone meal, defluorinated phosphate, and dicalcium phosphate all have essentially equal availability of calcium. Feedstuffs of vegetable origin are also generally considered as having fully available calcium.

This is not the case with phosphorus. Sources vary widely in amount of the available phosphorus. Cereal phosphorus is inadequately utilized by poultry. For example, chicks and turkeys from 8 to 20 weeks of age do not utilize phytin phosphorus to any great extent. In addition, inorganic phosphates differ widely in biological value. Thus, total phosphorus can be a misleading term.

Recommended Calcium Phosphorus Ratio.—The National Research Council recommends a calcium-phosphorus ratio of 1.67:1 for broilers, based on total phosphorus. If available phosphorus is used the ratio becomes 2.2:1. To be most valuable, requirements for phosphorus should be expressed as available phosphorus rather than total or inorganic phosphorus. Under practical conditions, broiler rations should contain a minimum of 0.45% available phosphorus which means roughly 0.7% total phosphorus, as well as 0.8% total calcium. Starting poultry should receive at least 1% calcium and 0.5% available phosphorus which calculates to 0.9% total phosphorus.

In growing turkeys, a minimum of 1% calcium is suggested with available phosphorus content of 0.5% or a total phosphorus of 0.85%. Energy content of the rations influence the requirements for both calcium and phosphorus. The National Research Council suggests a calcium level for laying hens of 2.75% which level may not be sufficient for old hens kept in cages during hot weather. Most major feed companies today put out rations containing 3 to 3.5% during winter months and from 3.5 to 4% in summer time.

Calcium Requirements of Laying Hens.—A number of factors affect the calcium requirement of layers. The larger the hen and the higher the egg production, the more calcium is needed. Also, the smaller the hen and the lower the total feed intake is, the higher the calcium level should be. Research indicates that at a dietary level of 800 Cal per lb of feed and 80% production, hens can get by on 2.9% calcium. On the other hand, if the energy level in the feed is stepped up to 950 Cal, then the hen needs 3.5% calcium in the ration. Birds in cages have a higher requirement for calcium than do floor layers.

In general, a little better egg shell is obtained if the calcium level is increased to about 5%; however, certain problems arise when the level is above 4%. High levels of calcium produce too many small eggs, lower egg production, and result in poorer feed intake. Some poultrymen feel that the necessary phosphorus level for birds maintained on the floor is 0.45%, and for caged birds 0.6%. In some cases, just increasing the vitamin level in the feed produces better egg shells. If the birds are bothered by certain disease problems, absorption of minerals and vitamins may be interfered with. Some poultrymen use a combination of ground limestone and oyster shell to improve palatability. Mash feed being moved through the house via a

mechanical feeder may cause calcium to separate out. In general, most poultrymen like to feed a certain amount of oyster shell free-choice, although this is unnecessary if proper amounts of calcium are in the complete ration. Oyster shells do improve the flow of mash feeds into the feed hopper and through automatic feeders, since they do not separate or settle out as does finely ground limestone. The amount of calcium in the laying ration may have a definite bearing upon the cracks and checks of eggs produced by the flock.

Sources of Calcium.—Economical sources of calcium are limestone and oyster shells. Oyster shells used for poultry feeding are not obtained from shucking oysters. It is the shell that remains of shellfish which are found in deep beds in the South. They are really geological deposits millions of years old, found sometimes 100 miles from the coast.

Some sources of calcium contain phosphorus. Bone meal made from the bones of slaughtered animals by the packinghouse industry has been used for years as either bone meal or bone char. Some additional sources of calcium and phosphorus are phosphates deposited on certain islands of the Caribbean. The dung of birds deposited over many years had weathered, such as that of Curacao Island phosphate. This is an island off the northern part of South America and contains the excreta of birds (guano) over many years. This particular product has a low fluorine content. Another source of phosphorus is the so-called "colloidal" phosphate. This is ground phosphate rock from Florida and is a by-product when phosphate was processed for export to Europe some years ago. This material mingled with clay is a colloidal type of product. One unfortunate part about this phosphate is that it is rather high in fluorine. Therefore, the amount that can be fed is limited. Probably the standard by which the availability of phosphate is judged is dicalcium phosphate which is produced from phosphate rock by chemical means. This product is being used more and more because it is uniform and low in fluorine. There is also defluorinated phosphate. This is phosphate rock exposed to very high temperature—1,832°–2,552° F. The fluorine is combined with silicon and volatilized. Some of this rock is treated with either sulfuric or phosphoric acid to produce superphosphate previous to heat treatment. Some of these calcium and phosphorus supplements are used. Whether a particular product is used or not depends not only on the cost but on purity of the product. There is no easy way to determine biological availability of a mineral such as phosphate. It has to be fed to test groups in order to determine biological results.

Despite the fact that bone meal is so similar to the bones of chickens, its availability is not as high as one might think. Fluorine occurs to a greater or less degree in all phosphate supplements. In large amounts it is a poison

and accumulates in the body of animals. In poultry, too much fluorine results in poor appetite and unthriftiness; since it is an accumulative poison, it is a serious problem. Poultry are more tolerant of fluorine than cattle but the fluorine content should be considered when a calcium phosphate supplement is selected.

To evaluate availability of phosphate in supplements, pure tricalcium phosphate is placed at the top of a scale of 100. On this scale, steamed bone meal is about 80. Chemically, pure grades of dicalcium, potassium and sodium phosphate run about 100, Curacao phosphate rock about 83.

The mineral reserves in animals are in the zillions of tiny crystals located in and around sheaths and bundles of collagen fibers. Bones contain about 60% inorganic substances, 20% collagen, and 15% water. About 5% of the body are cells.

Body fluids are in contact with this great mass of crystals. For bone formation, three organs are involved, intestines, kidneys, and the bone itself, and at least one hormone, parathyroid hormone, and vitamins A and D. Bone deformities occur with vitamin A and D deficiencies.

Vitamin A is concerned with the need for providing normal matrix as a site for mineralization. Very little is known of the effects of B-complex vitamins on bone. The intercellular substances of the supporting structures (the cartilages and fibrous connective tissue) are important. Bone is not dead but alive and in intimate contact with the rest of the body. During the period of deposition of mineral elements, bone is growing.

Feeding too much mineral is a problem. If fed to excess calcium and phosphorus supplements adsorb trace minerals and are excreted together. If the amount of bone meal is increased considerably in a diet which takes care of minimal needs for manganese, the animal would come down with perosis or a manganese deficiency. This is also true with zinc.

Calcium Supplements

Limestone is used in poultry feeds. Dolomitic limestone high in magnesium should be avoided. Oyster-shell flour or calcium carbonate may be used as a source of calcium, but in the Midwest finely pulverized limestone is usually more economical.

Phosphate Supplements.—Defluorinated rock phosphate, steamed bone meal, raw rock phosphate, monocalcium phosphate, colloidal phosphate, sodium and potassium phosphate are used depending on the biological availability of the phosphorus, fluorine content, and costs (Table 16.1). Phosphorus and steamed bone meal in defluorinated rock phosphate is 85 to 100% as available as that in calcium phosphate. Colloidal phosphate contains up to 1.25% of fluorine, so it is necessary to limit the level used in certain feeds.

TABLE 16.1

CALCIUM, PHOSPHORUS AND FLUORINE CONTENT OF CERTAIN MINERAL SUPPLEMENTS

Supplement	Calcium %	Phosphorus %	Fluorine %
Phosphorus supplements			
Steamed bone meal	24	12	0.05
Special steamed bone meal	26	13	...
Raw bone meal	22	10.5	...
Precipitated bone flour	25	16.6	...
Spent bone black	[illegible]	13	...
Monocalcium phosphate	20	21	...
Dicalcium phosphate	24	18.5	0.01–0.02
Dicalcium phosphate (feed grade)	26	20.5	0.01–0.05
Tricalcium phosphate (tech. grade)	38	18	...
Phosphate Curacao Island	35	15	...
Monosodium phosphate	...	22.5	...
Disodium phosphate	...	8.7	...
Defluorinated rock phosphate	33	18	0.05–0.3
Phosphate limestone	36	4.5	...
Minerals containing high amounts of fluorine			
Raw rock phosphate	29	13	3.5
Defluorinated calcium phosphate	30	13.0	0.1–2.0
Soft phosphate with colloidal clay	18	9.0	2.0
Treble superphosphate (fine)	15	19.8	1.9
T.V.A. metaphosphate	17	21.5	0.63
Calcium supplements			
Oyster shell, finely ground	38	...	...
High grade limestone	38	...	...
Calcium carbonate	40	...	...
Gypsum	25	...	...
Wood ashes	21	...	...

Magnesium

Magnesium is somewhat related to calcium in its metabolism, since it is involved in bone, muscle, and nerve health. Usually there is sufficient magnesium in feed ingredients used to formulate practical feeds.

Poultry trace mineral mixes are available to be added at the rate of a few pounds per ton. One recommended for this use is shown as follows:

	1 Lb of Trace Mineral Premix Provides
	Mineral Content per Ton of Feed (Mg per Lb)
Manganese	27.20
Iron	9.07
Iodine	0.54
Copper	0.91
Zinc	0.045
Cobalt	0.09

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Sodium, Potassium, Chlorine and Salt (NaCl)

Sodium, potassium and chlorine are almost entirely in body fluids or soft tissues. Their chief function is to help maintain acid-base and ionic balances in body fluids. In the absence of sodium chloride (table salt), animals develop depraved appetites. Muscular atrophy, lung infection, poor bone growth, changes in eye structure, and an inability to deposit fat accompany this deficiency. Death occurs after long periods of deficiency.

Poultry can tolerate excesses of salt better in feed than in water, but too much salt can cause edema or a water-logged condition of the soft tissues. A potassium deficiency produces sterility, fragile bones, kidney impairment, and heart damage. Potassium is adequate in most practical rations. If excessive dehydration occurs due to prolonged diarrhea or blue comb, it helps restore the birds to a proper balance of potassium ion at the cellular level.

Like air, water, and sunlight, salt (NaCl) has been rated important throughout the ages in the feeding of livestock and poultry. Salt functions in a variety of ways in the avian species. Health, growth, production, and life itself depends on the presence of salt and its component parts sodium and chlorine. Digestion, respiration, and many other body processes involved are greatly impaired when salt is withdrawn from their rations. Salt deficiency causes unthriftiness and loss in weight and production. Salt is sometimes used as a carrier of additives for the prevention of trace mineral deficiency diseases and internal parasites.

Chickens can tolerate rather high levels of salt in the feed; although above 4% may increase mortality, slightly higher levels are not immediately toxic. Levels in the feed markedly in excess of requirements result in excess water consumption resulting in wet litter conditions. Salt in the drinking water of poultry is much more toxic than in the feed. One-half percent added salt in the feed is adequate but at times may be excessive if the diet contains liberal amounts of products of animal and fish origin which contain some salt. Turkeys are more sensitive to salt excesses than chickens. It is thought that salt influences the palatability of feeds. Salt

has a sparing action of sodium on potassium, manganese, and phosphorus. Salt requirement is lower on high-energy, low-fiber diets.

A deficiency of salt (NaCl) in poultry diets causes retarded growth, reduced egg production and generally suboptimal performance. Excessive salt results in increased water consumption, watery feces, generalized tissue edema, hydropericardium, visceral edema, nervous reactions, depressed performance, and death. Tolerance to salt depends on specie and age of birds, route of salt administration, composition of diet, and levels of other elements present which are interrelated with either sodium or chlorine. Much early work was concerned with salt toxicity. A half to one ounce of salt kills a hen in 8 to 12 hr. Salt in solution is more toxic than equal amounts in the feed. Chickens from 21 weeks of age could be fed up to 8% salt with no apparent detrimental effects. However, 1% resulted in faster growth, earlier egg production, and more eggs. Five percent in the poultry diet was more than desirable; 2% was not injurious. Over 1% resulted in more than normal water intake, resulting in wet litter. Water consumption increased linearally with the percent of salt added to the diet as an attempt on the part of the organism to maintain isotonicity of the body fluids. Addition of more than 4% salt causes prolapse in some cases. A level of 0.9% salt in the drinking water is extremely toxic to fowl. Two percent in the drinking water results in mortality of all chicks in three days with obvious signs of diarrhea, generalized tissue edema, and water accumulation.

Chicks exhibit individual differences in tolerance to sodium chloride. Low concentrations in the water are roughly as toxic as that of an approximate equivalent intake of salt incorporated in the mash. Cardiac hypertrophy as well as increased tortuosity and medial hypertrophy of renal arteries and preglomerular arteries are constant findings with excessive salt intake.

Interrelationships of Salt and Other Elements.—Salt, however, is beneficial in poultry rations. Up to 1% of added salt greatly enhances growth promoting value of a diet. The salt requirement of chicks is influenced by several factors. Among these are the fiber content of the ration. On a low-fiber, high-energy diet maximum growth was obtained with 0.25% or less added salt. As the fiber was increased, the salt requirements increased progressively to 2%. Diets deficient in calcium and phosphorus have a lower requirement for salt. As the level of phosphorus increases, there is a sparing action by this element on salt. With high levels of calcium, there is an antagonistic interaction between this element of salt. Salt also increases the dietary requirement of manganese. Increased amounts of salt increases water intake and raises the moisture content of the droppings. No effect on mortality is observed on salt levels up to 4%, at which time the droppings

are very liquid. The sodium requirement for young chicks is between 0.1 and 0.3%. The requirement for chloride (Cl) is 0.06%. Both sodium and chlorine are toxic if fed excessively. The level of potassium in the diet does not appear to affect the sodium requirement.

Hatchability on low potassium diets is greatly impaired and relatively unaffected by low sodium diets. Turkey poults fed 2, 4, 6, and 8% salt showed high mortality at the 2 higher levels. Those receiving 4% lived several weeks but made no gains in weight. Turkey poults can tolerate up to 2% salt in the diet to 23 days of age; 2.5% salt results in edema, ascites, and death. Mortality is 38.4% on a 2% level of salt as compared with 9.6% on a 1% level. From 0.15 to 0.2% sodium in the diet is required for turkeys to four weeks of age for maximum gain and feed efficiency. A level of 0.4% sodium chloride was required in a corn-soy diet with no animal protein. With older poults, an increase in water consumption occurs with increasing levels of salt with no effect on mortality, weight or feed efficiency.

With pheasants and quail, the chlorine requirement is between 0.048 and 0.11%. The addition of 0.15% salt to the diet satisfied both pheasant and quail requirements. It takes 7½% salt before growth is markedly depressed and mortality increased. The moisture content of the droppings increases appreciably as the salt content increased.

With ducks, a level of 1% is required to produce mortality, but growth is retarded with 0.4%. Thus, ducks tolerate slightly higher salt levels than either chicks or turkey poults. Excessive salt intakes result in conditions ranging from a mild diarrhea to the extreme condition referred to as salt poisoning. Salt should not be added indiscriminately to poultry rations. One should take advantage of that supplied by ingredients, particularly when high levels of animal products are used.

Regardless of the way in which nature manages the soil, the loss of certain minerals is almost inevitable. The mineral which almost universally must be added to livestock and poultry rations is sodium chloride—ordinary salt.

Salt is so readily soluble it has been leached by percolating water ages ago. The acid partners of sodium—chlorine or iodine—are also leached out. The Great Lakes region, the Northwest states, Switzerland, the Pyrenees, New Zealand, the Himalayan mountains and a number of other places on different continents are examples of this.

Sodium, chlorine and potassium are found almost entirely in body fluids or in soft tissues and *maintain acid-base balance. On a sodium-free diet,* poultry develop muscular atrophy, lung infections, poor bone growth, and changes in eye structure. From 0.25 to 0.5% of salt prevent these conditions and also supply chlorine.

Potassium deficiency causes fragile bones and kidney and heart im-

pairment. Most practical rations supply adequate amounts of potassium. Potassium deficiency is often encountered where purified rations are used for experimental purposes. It is not usually a problem in practical feeding. Natural feed ingredients vary widely which sometimes make calculations of limited value. Similar ingredients may differ widely, for example, cane molasses is an excellent source of potassium, whereas citrus molasses contains very little. Brewers and torula dried yeasts differ widely in zinc content which probably reflects the mineral content of the media on which the yeasts are grown.

The Role of Sulfur

Sulfur is required principally as an essential part of the sulfur-bearing amino acids, methionine and cysteine. It is also part of several hormones, enzymes, and bile salts.

Many feedstuffs provide inadequate amounts of sulfur amino acids. Sulfur is intrinsically involved in protein synthesis per se, as well as instrumental in the utilization of phosphorus, which next to sulfur is man's most critical defense line. The phosphorus cycle differs fundamentally from carbon, nitrogen, and sulfur cycles in that no natural channel exists for the return of large annual net loss. In the extreme vegetable diet there is a relative shortage of lysine, threonine, and tryptophan.

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TABLE 16.2

REQUIREMENT, TOLERANCE LEVEL AND TOXICITY LEVEL OF TRACE MINERALS FOR POULTRY

Mineral Element	Requirement Ppm		Tolerance Level Ppm		Toxic Level Ppm		Safety Index—Toxic Level-Requirement Level	
	Growing Chicken	Hen	Growing Chicken	Hen	Growing Chicken	Hen	Growing Chicken	Hen
Cobalt	>5	?	5-10	?	>10	?	...	...
Copper	4	4	300	?	500	?	125	?
Iodine	0.35	0.30	180	50	180	50	514	167
Iron	75-80	40	?	?	?	?	?	?
Magnesium	500	900-1000	2000 +	13,300	6400	?	12.8 +	>11
Manganese	55	50	1000	1000	>1000	>1000	19-87	>20
Molybdenum	?	?	?	?	< 100	?	<50	?
Selenium	0.10	<2	<5	<8	<10	8	50-100	?
Zinc	35	50-80	1000	1400	1500	?	43	>20
Fluorine	...	...	300-400	500-700	<700	?	...	...

< Less than
> More than

Iron is generously distributed among various common feedstuffs but that in green leafy tissues is less available biologically than in the grains. Excess iron lowers the availability of phosphorus and manganese. As little as 2 lb of ferrous sulfate to a ton of feed detrimentally affects bone growth in chicks. A deficiency of copper in the ration leads to nutritional anemia even in the presence of adequate iron. About 1/10 as much copper as iron is adequate. The requirement for copper is also influenced by cobalt, iron, and molybdenum.

Additives

Trace minerals are essential nutrients for poultry. Some are also used as feed additives which does not relate to their need as a nutrient. Feed additives are not in the ration as true nutrients, since they are used at levels above those for normal growth. They have an influence on intestinal microorganisms and thus improve the health of the animal. All poultry operations have an "environmental disease" level. The greater the disease buildup, the greater the response to feed additives. There is controversy as to whether continuous feeding of an additive gradually decreases its effectiveness. Sometimes periodic changing of drugs is employed.

Certain feed additives are actually drugs which are absorbed and retained in the meat in quantities that may be harmful to man. The U.S. Food and Drug Administration is responsible for approving drugs and establishing tolerances of a chemical that can be used. To avoid contamination in the meat, some drugs must be withdrawn from the ration prior to slaughter, according to the directions stated on the package.

Chemical and spectrographic analysis of poultry tissue and its products reveal the presence of a large number of trace elements. It is not known whether some fulfill a physiological role or are simply incidental to the ingestion of the feeds containing these elements. Some, when fed in excess are toxic. The mineral elements which have been recognized as essential nutrients for the domestic fowl are Na, K, Ca, Mg, P, Cl, Fe, I, Mn, Cu, Co, and Zn. The essential trace elements presently thought to be required by domestic fowl are Mo, Cu, Zn, Mn, I, Co, and Fe. The general functions of the mineral elements are that they: (1) help contain osmotic pressure; (2) are concerned in regulation of hydrogen ion concentration; (3) influence degree of irritability or ability to respond to muscle and nerve stimuli; (4) constitute an integral part of living protoplasm; and () constitute the greater part of bones, giving rigidity to the skeleton. Common to all trace elements is that they function in small quantities in some catalytic role and may act as catalyst involved with a hormone or an enzyme system.

The history of the discovery of the nutritive value of trace minerals is

one of the most fascinating in the whole field of animal nutrition. The most productive era of trace mineral investigations had its beginning during the 1920's when copper was found to be essential in the diet of poultry. Through the 1930's discoveries were made involving manganese, iodine, and cobalt; during the 1950's the need for zinc was studied; during the 1960's researchers pinpointed required levels and demonstrated the existence of interrelationships and interactions of these minerals. Trace minerals are not related physiologically. The main thing they have in common is their ability to function and do important jobs when present in extremely minute (trace) quantities.

The Discovery of the Need for Minerals in Poultry Rations

It was comparatively easy for scientists to segregate from feed the "big three nutrients"—sugar, fat, and protein—and give them Greek names. At first, these nutrients seemed to be all that poultry needed. Scientists were astonished, therefore, that animals died when these nutrients were fed in pure state. Digging deeper they found that the ashes left after the "big three nutrients" were burned (ashed) was a missing factor. The ash contained principally the metals sodium, calcium, magnesium, iron, manganese, copper, cobalt, iodine, zinc, potassium, and the nonmetals sulfur, phosphorus, and silicon. These were called minerals because roots of plants gather them from the soil and bring them up into the plant.

It was first thought that the presence of these minerals was accidental. Elements got dissolved in water and were drawn up by the plants. But these elements were found in every cell of the animal's body. Proof of their vital need in the cell soon followed.

The minerals originally came from old rocks that made up the crust of the earth. They are supplied either through the soil to the plants the animals eat or the animals directly as part of their feed. After the "big three nutrients" were found wanting in something and the minerals were found to be part of that something, there was still a missing link, which turned out to be vitamins. Scientists kept on analyzing the mineral needs of animals and were astounded at the next discovery—that animals cannot live or even breathe without an infinitesmal allowance of certain minerals. If one of the minerals is deficient in the cell, the whole cell is affected and the quantities of all other elements in the cell are reduced in proportion commensurate with the level of the deficient element.

No one knows how far back the practice goes of dumping of wood ashes in the barnyard where animals could get at them. Most of the minerals required by the animals in minute quantities are present in ordinary grains and grasses, but occur in insufficient quantities. Six trace minerals most likely to be deficient in the feed ingredients and thus in the diet of poultry

are manganese, zinc, iodine, copper, cobalt, and iron. In certain instances molybdenum and selenium also may prove beneficial, but have only a small margin of safety and are toxic in amounts only slightly above required levels.

How Trace Minerals Work

How do trace minerals do their important work? They primarily involve an association of trace minerals with complex proteins exhibiting enzymatic activity and with other functionally active compounds, for example, iodine with the hormone, thyroxin, cobalt with vitamin B_{12}, and iron with hemoglobin. These minerals are involved intimately in such important body functions as energy utilization, hemoglobin regeneration, feather development, pigmentation, bone development, skin development, control of body metabolism, and maintenance of a normal appetite and growth. They are essential for the animal to make the most efficient and economical use of feed.

Even though visible symptoms are not apparent, animals can suffer from border-line deficiencies that result in slow gain and poor feed conversions. The relationships of an excess or an inadequate amount of a specific mineral upon the utilization or availability of the others in the diet is one of the most intriguing phases of mineral nutrition. For example, excess calcium and phosphorus influence manganese and zinc requirements because of adsorption of the trace minerals and loss from the intestines. Certain proteins, like soybean meal, influence zinc utilization because of phytic acid, a naturally occurring chelating agent. High levels of copper tend to deplete the storage of zinc in the liver. Copper requirements are influenced by high levels of inorganic sulfates and molybdenum in the diet. Calcium levels influence iron and copper absorption by reducing acidity in the digestive system. Calcium levels influence iodine requirements. Excess manganese interferes with iron interrelationships and interactions, the feed formulator must also give some attention to the sources of trace minerals when supplying a requirement.

In the early days, trace minerals in water-soluble form were recommended because it was felt they would be more easily utilized by the animal. Later, it was found out that water-soluble compounds react with other nutrients in the feed in the presence of moisture and cause destruction of some nutrients. Mineral feed manufacturers now use water-insoluble compounds for the reason that they are less likely to complex and destroy other nutrients. The oxide and carbonate compounds are water insoluble, whereas the sulfates and chlorides are water soluble. The water insoluble trace minerals are dissolved within the body of the animal in the gastric juice in combination with the organic material in the feed.

Great strides have been made in pinpointing the quantitative requirements for different trace minerals. These findings have helped poultrymen do a better job of producing meat and eggs. As rations become more completely composed of plant materials, there is an increasing need for trace minerals. This is because animal protein supplements contain appreciable amounts of the trace minerals, whereas plant protein supplements do not.

Certain trace minerals have often played obscure and exceedingly important roles in plant and animal metabolism—some beneficial and some detrimental. External or critical manifestations of such deficiencies or excesses are at best unreliable as a means of diagnosis and are end results in metabolic disturbances that may exist undiscovered in many more animals suffering from lesser deficiencies. Hence, more precise and accurate means of ascertaining the requirements are badly needed.

Numerous factors alter the availability of essential cations. The most soluble and most absorbable form of any of the essential cations is its simple ionic state. However, many compounds in nature seek polyvalent cations in order to share their electrons to form stable compounds. In the animal, hydrochloric acid in the stomach or proventriculus tends to convert all the cations temporarily into chloride salts which for all the essential cations allow a considerable degree of ionic dissociations and, therefore, good absorption from the intestinal tract. Thus, some water-soluble compounds become available to the animal because they dissociate in their tract. This is particularly true of many of the trace minerals.

Sodium nitrate (675 ppm nitrate) in drinking water of Bronze poults during the first four weeks of life improves growth rate in market turkeys amounting to as much as an extra ½ to 1 lb of body weight. Males are more affected by this treatment than females. No such response is noted when other sodium or nitrate salts are employed in a similar manner, nor has the use of equivalent levels of sodium nitrate in the feed given similar results. This treatment has no effect upon the thyroid or thyroid function, blood glucose, blood lipids or hematocrit. Testes of treated birds are about ½ the size of control birds at 24 weeks of age. When male Leghorn chicks are exposed to the same water treatment, their 8-week testes sizes were only 62% of the size of the controls. This indicates that sodium nitrate may be upsetting normal gonadal hormone metabolism. The initial cost of the nitrate is insignificant compared with the effects obtained.

No satisfactory generalizations can be made that will take in all trace elements. In feed manufacture there is little likelihood of a deficiency of the trace elements, except in certain critical elements and these minerals can be added without much difficulty. Simple salts are all nutritionally available, except in the case of cobalt which needs addition as vitamin B_{12}. Be-

ware of extravagant claims made for trace elements. They are not cure-alls, particularly for infectious diseases.

Factors affecting the trace mineral contents of plants are the amounts in the soil on which they are grown, the nature of the soil, plant species, rainfall, stage of growth at harvest, and how the plants are processed. By contrast with other feeds, milk is markedly deficient in iron. Its amount cannot be significantly increased by adding iron to the maternal diet. Addition of trace mineral mixtures to home-mixed rations and to commercial mixed feeds is fairly common to prevent deficiency trace mineral diseases in poultry. They are successful, providing the mineral mixtures are carefully formulated and are mixed with the rations in correct proportion. Excessive trace mineral intakes produce adverse or even toxic effects.

The growing realization of the importance of trace minerals in the physiology of poultry (such as in enzymes) makes it desirable to obtain more extensive information on the metabolism of these elements (Table 16.3). Their minute requirements make it difficult to apply ordinary methods of chemical analysis. In many instances, this handicap can be overcome by means of tracer experiments with radioactive isotopes.

A bone abnormality occurs in chicks fed purified diets. The chicks grow normally and do not have leg weakness. The abnormal cartilage

TABLE 16.3

SPECIFIC ENZYMES CONTAINING TRACE MINERALS

Enzyme	Metal
Carbonic anhydrase	Zn
Dehydropeptidase	Zn
Glycylglycine dipeptidase	Zn
Carboxypeptidase	Zn
Alcohol dehydrogenase	Zn
Glutamic dehydrogenase	Zn
Lactic dehydrogenase	Zn
Inorganic pyrophosphatase	Mg
Fumaric hydrogenase	Fe
Catalase	Fe
Peroxidase	Fe
Cytochromes	Fe
DPNH-cytochrome c reductase	Fe
Uricase	Cu
Tyrosinase	Cu
Lacasse	Cu
Ascorbic acid oxidase	Cu
Butyryl CoA dehydrogenase	Cu
Prolidase	Mn
Nitrate reductase	Mo
Xanthine oxidase	Mo
Aldehyde oxidase	Mo

development resembles that in severe copper, calcium, and vitamin D deficiencies. But addition of these nutrients is without effect. Natural ingredients such as corn, soybean meal, and skimmilk seem to have a protective action. The causative agent has not yet been isolated but it does not appear to be mineral in nature. Fluoride or phytic acid (plant phosphorus) causes the abnormal cartilage condition on purified rations but not on practical feeds. Genetics also play a part. Broiler breeds show a greater tendency toward the condition than Leghorns.

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Some Producers of Trace Mineral Supplements:

Boron
- American Potash & Chemical Corp.
- Stauffer Chemical Co.
- Tennessee Corp.
- United States Borax and Chemical Corp.

Magnesium
- Johns-Manville Corp.
- Rayonier, Inc.
- Tennessee Corp.

Iron
- Davies Nitrate Co. Inc.
- Eagle-Picher Industries, Inc.
- Flag Sulphur and Chemical Co.
- Geigy Agricultural Chemicals
- Hampshire Chemical
- Rayonier, Inc.
- Tennessee Corp.

Zinc
- Chevron Chemical Co.
- Davies Nitrate Co.
- Dow Chemical Co.
- Eagle-Picher Industries
- Flag Sulphur and Chemical Co.
- Geigy Agricultural Chemicals
- Hampshire Chemical Div., W. R. Grace & Co.
- Rayonier, Inc.
- Tennessee Corp.
- The Sherwin-Williams Co.

Copper
- Davies Nitrate Company, Inc.
- Geigy Agricultural Chemicals

The Role of Iron

Iron is a constituent of hemoglobin in the red blood cells which act as a carrier of oxygen which, in turn, is essential for all cellular metabolism. It is required also for the respiratory or oxidizing enzymes such as cytochrome for oxidation of catylase. A lack of iron causes nutritional anemia, depigmentation of feathers, and a decrease in hemoglobin and in size of red blood cells.

Ordinarily the young are born with sufficient iron to carry them through early growth. Inorganic iron in feed is readily converted to iron salts by action of hydrochloric acid in gastric juice. These iron salts are utilized by poultry. Iron is stored in the liver, bone marrow, and spleen. Iron is widely distributed among various common feedstuffs. That occurring in green, leafy tissues is less available biologically than in grain. Unless dietary iron is supplied, anemia is produced rapidly in the chick. Feeding an excess of iron interferes with normal bone development and normal hematopoiesis. Iron, in excess, lowers the availability of phosphorus and manganese. Commercial poultry diets supply an ample quantity of iron, even though ingredients are known to vary with different soils and climatic conditions.

The Role of Copper

Copper is an essential nutrient for poultry. A number of copper protein compounds isolated from both plant and animal sources are enzymes with an oxidase function (urocase, tyrosinase, ascorbic acid oxidase). Liver, heart, kidney, bone marrow, spleen, hair, and brain contain the highest concentrations of this element, with the liver being the main storage organ. The demand of the laying hen for copper is not great.

Copper is required for the utilization of iron in hemoglobin formation and has an important role in oxidation reduction systems. A deficiency of copper in the ration leads to nutritional anemia, even in the presence of adequate iron. Localized areas in Sweden, Australia, Great Britain, Holland, New Zealand, Peru, Africa, and Florida lack copper in local forages. Copper deficiency in chicks causes retarded growth, produces high mortality, severe leg weakness and bone deformities and large incidences of subcutaneous hemorrhages and internal hemorrhages at death. About 1/10 as much copper as iron is adequate. Excess of copper in the ration is toxic.

Some poultrymen have used copper sulfate to prevent or reduce the algae or fungi in water. Others treat crop mycosis in the birds on occasion with this chemical. Administration may be either by water or feed, although the most common method is water medication. There are potential hazards of administering large amounts of copper sulfate to poultry. Extremely high levels of copper are unpalatable to chicks. A level

of 2,000 ppm of copper in drinking water was toxic to turkeys. There is a further harmful effect in using copper additions in the presence of low levels of iron in the laying hen's diet. While copper sulfate is an effective fungicide, additions of high levels of copper in the laying hen's diet cause interfering interactions with other minerals.

Excess copper also hastens destruction of certain vitamins in the feed. Copper sulfate reacts with galvanized feeders and waterers to hasten destruction of the metal. Slime bacteria are a problem in poultry and hog watering troughs. However, treatment of this bacterial condition can be accomplished effectively and with greater safety by use of water disinfectants. Quaternary ammonium compounds will effectively control this problem at low cost without interfering with the birds feed or equipment.

Nutritionists visualize a balance of feedstuffs which provides all the dietary nutrients in a respect to kind, amount, and proper state of combination, so that poultry may meet the varied exogenous and endogenous stresses of life in health and disease with a minimal demand or strain on the body's natural homeostatic mechanism. The most practical guides available for judging nutritional adequacy are the Tables of Recommended Dietary Allowances prepared by the National Research Council. The latter are based on experiments with poultry and clinical observations, as well as considered judgment from evaluation of extensive nutritional literature. They contain a substantial safety factor well above the minimal needs. However, the nutritional needs of the sick are considerably in excess of the recommended levels of dietary allowances. Therapeutic nutrition recognizes the flexibility of nutritional needs based upon the stresses to which the individual is exposed.

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The Role of Manganese

Recognition of the importance of manganese came as a result of studies of perosis which is characterized by enlargement and malfunction of the tibial metatarsal joint and subsequent slipping of the gastronemous or Achilles tendon from the chondyles. Nutritional chondrodystrophy results from a manganese deficiency in the maternal diet. Symptoms are a shortening and thickening of the legs and wings, "parrot" beak, edema, and protruding abdomen. Manganese deficiency produces ataxia, retarded growth, failure to maintain body weight in mature fowl, decreased egg production and hatchability, and reduced egg shell quality. Factors affecting the manganese requirements of poultry are the breed and strain of birds, the level of production, and calcium-phosphorus ratio in the diet. The latter is of great importance. Some unfavorable ratios of calcium-phosphorus cause perosis due to adsorption by the solid mineral of soluble manganese which is then lost in the feces. Blood and bone phosphatase activity of perotic chicks are significantly below normal. Although the vitamins choline, inositol, niacin, riboflavin, and folic acid have been associated with perosis, there is no substitute for manganese.

With turkey poults, manganese deficiency causes reduced growth and perosis. The tolerance of poultry for manganese is unusually great—1,000 ppm of manganese is not toxic to day-old chicks. Lack of direct sunlight or vitamin D increases the need for manganese. The salts of manganese such as sulfate, chloride, carbonate, and oxide are all equally available to chicks, however the natural carbonate ore, rhodochrosite, is not.

Although manganese is essential for the growth of most plants, the quantity removed from the soil is small and varies greatly according to species of plant. Corn, for example, contains on an average only 5 ppm of manganese, whereas wheat and oats have 39 and 34 ppm, respectively. The marked difference in manganese content accounts for the fact that following the development of a more intensive system of rearing chickens, perosis or slipped tendon was encountered in this country more frequently than in England. Ear corn is the chief ingredient of feed mixture for chickens in the United States, whereas in England wheat and oats are used. Prior to 1926, when chickens were raised on soil, perosis was comparatively rare. With the development of the battery brooder and the year-round production of broilers, it became quite common and caused heavy

losses. By 1931, it had been found that rice bran, wheat bran, and wheat middlings in the diet of growing chicks reduced the incidence of perosis, but the reason for the beneficial effects of these feedstuffs remained unknown. Following the discovery in 1936 of the importance of manganese in perosis, it soon was found that manganese was essential for hatchability and the formation of good egg shells.

The Role of Cobalt

Cobalt is required by tissues that produce hemoglobin and red blood cells. A deficiency of cobalt causes nutritional anemia even in the presence of adequate iron and copper. It is a part of vitamin B_{12}, the antipernicious anemia factor. A deficiency of cobalt is characterized primarily by a loss of appetite.

A lack of cobalt in the soil results in low levels in the forage plant. Deficiency areas are found in Australia, New Zealand, Great Britain, South Africa, and parts of the United States, specifically, Florida, Massachusetts, New Hampshire, Michigan, New York, Wisconsin, and North Carolina. Cobalt nutrition in poultry is associated only with vitamin B_{12} for normal chick growth and reproduction in the mature fowl. Hatchability, egg production, and egg size are increased upon addition of cobalt.

Cobalt is involved in the stimulation of tissues which produce hemoglobin and red blood cells. In extreme cases, wasting away and death are evidently due to starvation following loss of appetite. Excesses of cobalt are detrimental but toxic levels for poultry appear to be many times the level usually advocated in supplemental feeding of this element.

The Role of Zinc

Zinc is essential for the growth of poultry. It is present in the prosthetic group of the enzymes, carbonic anhydrase, alcohol dehydrogenase, and carboxypeptidase. Zinc plays an important role in acid-base equilibrium, facilitating the conversion of CO_2 derived from the tissues to H_2CO_3 in the blood, and in the breakdown of H_2CO_3 to release CO_2 in the lungs. Carbonic anhydrase plays a role in the calcification of bone and in the formation of egg shell. High concentrations of the enzyme occur in that portion of the oviduct in which shell formation takes place. Poultry is rather tolerant of zinc and can tolerate zinc supplements at levels several thousand parts per million of the diet.

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The Role of Molybdenum

Molybdenum is an essential nutrient involved in an enzyme reaction (xanthine oxidase) that converts purines to uric acid for excretion. Practical diets are not deficient in molybdenum since it is present in most grains and legumes. An excess of molybdenum is toxic. "Alkali disease" occurs in animals fed relatively high levels of selenium. Growth, egg production, and hatchability are decreased.

It is apparent that molybdenum is a dietary essential under certain conditions, since a growth response from molybdenum occurs in both chicks and poults fed purified diets. A portion of the growth promoting activity of the ash of distillers dried solubles is due to its molybdenum content. The molybdenum-containing enzyme, xanthine dehydrogenase, shows a greater activity in those instances when molybdenum is fed. The addition of molybdenum to practical poultry rations has not been checked for beneficial effects and is presently not recommended.

The Role of Selenium

Although selenium was considered toxic to poultry for some time, it has finally become recognized as an essential trace mineral for poultry and other species. The close chemical relationship of selenium to sulfur, arsenic, and phosphorus compounds emphasizes the biological importance of this element. In fact, these elements have a protective value against selenium toxicity.

Selenium is present in animal proteins as seleno-amino acids which are formed by the animal from the reduction of selenates and selenites. It plays an important role in the activation of some of the enzymes involved in decarboxylation. A selenium compound acts as a carrier of vitamin E and affects the absorption, protection, and transfer of D-alpha-tocopherol. Some selenium compounds are powerful antioxidants and some of its major functions depend on this activity. End products of selenium metabolism are cysteine, selenic acid, selenocysteic acid, selenites, and selenates.

Some metabolic functions of selenium are the prevention of: (1) muscle abnormalities (myopathies), (2) exudative diathesis, and (3) gizzard erosion in turkeys. Myopathies include: nutritional muscular degeneration, white muscle disease, muscular dystrophy, stiff lamb disease, myositis, white flesh, fish flesh, and waxy degeneration. Selenium nutrition is related to the function of vitamin E. In the absence of dietary vitamin E, selenium prevents exudative diathesis in chicks, poults, and quail, and gizzard erosion and cardiac myopathies in turkey poults. It spares the vita-

min E requirement for the prevention of these disorders. Quail chicks and turkey poults fed a practical type diet containing all the known nutrients do not grow at maximal rate unless the diet is supplemented with 0.1 ppm selenium as sodium selenite. Selenium deficiencies occur more frequently in turkey poults than chicks.

Cornell researchers have demonstrated a deficiency of selenium in the chick. In earlier work it was shown that a deficiency of selenium could be produced, but that this could be prevented by the addition of vitamin E or selenium to the diet. In recent studies, vitamin E was ineffective in preventing the selenium deficiency symptoms. Thus, there is no longer any doubt as to the role of selenium as an essential nutrient.

A German scientist, Schwartz, used brewers' yeast in feeding rats during World War II. When he came to the United States later, he used torula yeast. This yeast has different nutritional values than that of brewers' yeast. One difference was found to be the trace mineral selenium.

Interrelationship of Selenium and Vitamin E

Selenium fed sodium selenite at high levels is very toxic. Selenium promotes growth as does vitamin E, but it eliminates only some of the symptoms of vitamin E deficiency. About the same time, in New Zealand, exudative diathesis was prevalent in commercial flocks of poultry and a white muscle disease in lambs and calves. These had been economic problems for years. There was a lack of available selenium in the forage of that area and vitamin E or selenium had to be provided. This demonstrated that the element, selenium, must be included in the list of nutritionally essential trace minerals and showed the relation of a vitamin (E) to the mineral selenium.

The addition of selenium has some effect in reducing the incidence of muscular dystrophy in chicks raised on a vitamin E deficient diet. Later, it was found that certain sulfur containing amino acids also are involved in this relationship. Both selenium and vitamin E are concerned in the prevention of muscular dystrophy in chicks and calves. In some areas, feeding a diet high in unsaturated fatty acids has brought about muscular dystrophy in domestic animals which responded only to vitamin E. It was found that the amino acids, specifically sulfur containing amino acids such as cystine and arginine were also involved. Though vitamin E is a very important metabolite, its mode of action is still a mystery. Everything has not been learned as yet in this area. No doubt, much of the value of vitamin E relates to enzyme activity, particularly to the prevention of fat oxidation. The results strongly indicate that vitamin E has three functions in the chick. Selenium is completely unrelated to the function of vitamin E as a biological antioxidant in that it has no effect on encephalomalacia. Selenium

appears to be concerned with the other two functions of vitamin E involved in prevention of exudative diathesis and muscular dystrophy. Sulfur containing amino acids help also only in the prevention of muscular dystrophy.

The discovery that selenium and vitamin E prevent exudative diathesis and muscular dystrophy has resulted in greatly reducing the amount of alpha tocopherol needed, although it also helps prevent these diseases. Alpha tocopherol is nature's antioxidant for the preservation of linoleic acid and for the prevention of autooxidation of lipids inside and outside the cell. Even though certain synthetic compounds are able to fulfill some of the functions of vitamin E, the presence of sufficient vitamin E in the diet is the only way to be sure that all of these important functions in the body are being completely fulfilled.

Selenium Accumulators

Selenium is an unusual element in that some plants take up tremendous quantities of it and yet are not affected themselves. Some plants are accumulators and others are not. Regions in which selenium toxicity is known to occur includes 15 states in the northern Great Plains and Rocky Mountain regions, especially South Dakota, Wyoming, Nebraska, Kansas, Montana, Colorado, North Dakota, Oklahoma, Texas, New Mexico, Arizona, and Utah. The affected areas are localized and not general in these states. The mode of action of selenium is not known but it is thought that the ion acts as a poison of dehydrogenase in enzyme systems.

Selenium in Alkali Disease

Discovered in 1817, selenium was considered primarily a toxic material in conditions such as "alkali disease." Even today selenium is allowable in feeds only in New Zealand where levels of approximately 0.35 ppm are used against exudative diathesis and gizzard erosions in poultry rations, and white muscle disease of sheep. But it is now known that young quail, turkey poults, and baby chicks need selenium for growth and survival. Current U.S. regulations do not allow selenium to be added to feed, but there is a nutritional requirement for selenium. It can be expressed only in terms of a range since the actual need in given circumstances is inversely proportional to the parts of vitamin E activity in the ration. The problem is further clouded by the observation that arsenicals can accentuate selenium toxicity when both are in the drinking water, but not when one is in the feed and the other in water consumed by the animal. The toxicity of selenium can be modified also by the level of inorganic sulfate in the ration.

Selenium had been a source of trouble in the production of livestock for many years. The first written report of "alkali disease" or "blind staggers" was made in 1856 by an army surgeon stationed in the territory of Ne-

braska. The early settlers thought that the disease was caused by alkali waters common in the affected areas. Franke of the South Dakota Experiment Station began studies of the problem in 1929 and was joined later by Knight of the U.S. Bureau of Chemistry and Soils. Together they found that selenium was the culprit. Poultry are part of the cycle made up of soil, atmosphere, plant, and animal. In this cycle the same chemical elements are used over and over again. The animals draw their substance from the plant, these in turn from the soil, the soil from parent rock and from animal and plant decay. Soils have a great variety of minerals which are more likely to be retained in the soil instead of being leached out. Selenium is much higher in certain soils than others. Plants grown on these soils are seleniferous and are detrimental in feeding poultry.

Toxic levels of selenium cause malformations in chick embryos. To produce these metabolic changes the amount of dietary selenium required is 5 to 10 ppm. In the Corn Belt and the Mississippi basin, diets contain 0.5 to 2.0 ppm; in the East and West, less than 0.2 ppm of selenium. The nutritional requirement is 0.15 ppm for poultry receiving diets low in vitamin E. Nutritional diseases which have responded to selenium can be prevented also by vitamin E, but the amount required is higher than is normally present in an otherwise good diet of natural ingredients. No more than 0.04 ppm of selenium is required when selenium is protected by high levels of vitamin E. A level of selenium of approximately 0.01 ppm is specifically required for prevention of mortality in chicks and quail. This extremely low concentration places it in the category with vitamin B_{12}, biotin, and vitamin D, which have profound effects at low levels.

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The Role of Iodine

Iodine is associated with the thyroid gland and thyroid hormones. In fact, most of the iodine in the body is in the thyroid glands. Inorganic iodide constitutes only 1/10 of the total iodine present in the normal gland, whereas thyroid "colloid" thyroglobulin contains a very high proportion of the total. In iodine deficiency, the thyroid gland enlarges and the condition is commonly known as goiter. The thyroid increases to many times normal size and the enlarged gland shows an absence of "colloid" and hyperplasia in the cells of the follicle. Hatchability is greatly reduced and hatching time increased when there is a deficiency of iodine in the ration of breeders. Chicks and hens have a high tolerance for iodine.

Iodine and poultry nutrition have been closely linked with the feeding of antithyroid (goitrogens) and the thyroid-activating agents. Raw soybeans exert a goitrogenic effect on chicks which is inactivated by heating the soybeans. Rapeseed meal and thiouracil are also goitrogenic.

Iodine is supplied as calcium iodate, potassium iodide or as iodized salt. Potassium iodide is usually mixed with salt or calcium carbonate. A stabilizing agent is used to slow down the loss of iodine from potassium iodide, but the loss of iodine is not entirely prevented, especially when the mixture is exposed to sunlight, rain or excessive air movement. There are many regions where iodine is insufficient in the soil and consequently in the water and crops. The Northwest and the Great Lakes region of the United States are areas deficient in iodine.

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Silicon

For years, silicates were presumed to be biologically inert but recent work has indicated otherwise. Beneficial effects on egg production, feed efficiency, mortality, caloric efficiency, egg size, and also control of wet droppings have been reported. Most of the active compounds appear to fall in the mineralogical classification of phyllosilicates. They are known by various common names: hydrous layer silicates, micaceous layer silicates, kaolin, bentonite, vermiculite, and clay. A basic structure of some are a tetrahedral ("t") sheet and an octahedral ("o") sheet. Diatomaceous earth has some common physical properties but is opaline silicate, with an entirely different structure and activity. The more nutritionally active of these materials contain high levels of exchangeable cations such as potassium, magnesium, iron, sodium, or calcium. Smectite-vermiculite is a weathered phlogopite mined in southeastern Kansas which is high in exchangeable potassium, magnesium, and iron.

Bentonite is volcanic ash, found particularly around the Black Hills of South Dakota and Wyoming. Its name is derived from the fact that it was first found in the Fort Benton series of cretaceous H rocks in Wyoming and its chief constituent is Montmorillonite, named for a plastic clay found near the town of this name in France. There are two types: sodium bentonite, often called Wyoming or Western, which expands in water and carries sodium as its predominant exchangeable ion, and calcium bentonite, called Southern, which has negligible swelling and carries calcium as its principal exchangeable ion. Mined, dried, pulverized at various degrees of fineness, it is sometimes purified by the removal of grit. It is a colloidal native, hydrated aluminum silicate (clay) and its color varies from yellowish-white to black (Table 16.4).

Diatomaceous earth, derived from marine and fresh water diatoms, is distributed in substantial beds in Arizona, California, and the Pacific Northwest. This material is surface mined and pulverized. Diatom is defined as follows: any microscopic unicellular marine or fresh-water algae

TABLE 16.4

ANALYSIS OF BENTONITE

	%
Mechanically-held water	0.0
Silica (SiO_2)	63.07
Alumina Al_2O_3	21.08
Ferric oxide (Fe_2O_3)	3.25
Ferrous oxide (FeO)	0.35
Titanium oxide (TiO_2)	0.14
Lime (CaO)	0.65
Magnesia (MgO)	2.67
Soda (Na_2O)	2.20
Potash (K_2O)	0.37
Other minor constituents	0.58
Chemically-held H_2O	5.65

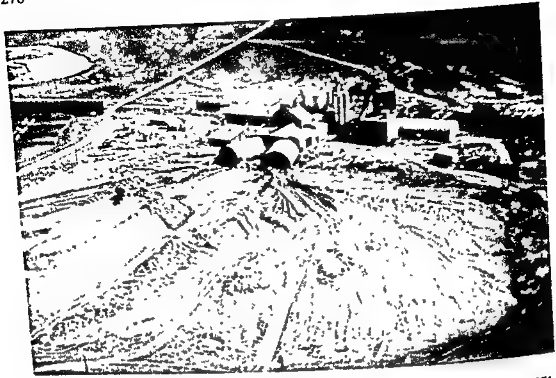

FIG 16 1. BENTONITE IS PRODUCED IN THIS PLANT AT BELLE FOURCHE, SOUTH DAKOTA BY VOLCLAY

belonging to the order Bacillariales, remarkable for the silicified cell wall, which persists as a skeleton after the death of the organism. Thousands of kinds of animals from protozoans to whales graze on diatoms as pasture, the basic food plant of the sea. Kieselguhr is a deposit of fine, usually white, siliceous powder, composed chiefly or wholly of the remains of diatoms. It is also called infusorial earth having been given the name before the true relationship of diatoms was known.

Kaolin is also a hydrated aluminum silicate, white or yellowish-white powder, unctuous when moist and used in medicine as an absorbent in diarrhea and as a dusting powder. Halloysite is the same chemical structure as kaolinite, but the flat platelets of kaolinite are curled or tubular in halloysite.

Physical Properties.—The particles of kaolins and bentonites are thin, flat plates like fish scales and billions of them are contained in each cubic inch of the substance. The dimensions of the particles place them in the colloidal range of size; physical effects are referred to as colloidal properties. The enormous surface area is responsible for the bonding of other minerals when slightly damp. Their tendency to absorb water is so avid that the tightly bound water film which a particle carries with it when saturated may be thick enough to increase the effective size of the particle from 10 to 15 times. This is the "swelling and gelling" phenomena. Bentonite is safe for both internal and external use.

The phyllosilicates are composed of elements arranged in a configuration called a lattice. Several lattices form a layer, and several layers a crystal. Water can enter between the layers causing the lattice to expand. Exchangeable cations are held by charges between the silicate layers. Clay materials have a property of adsorbing certain ions and retaining these in an exchangeable state. These ions are exchangeable for other anions or cations by treatment with such ions in water solution. Sodium bentonite is odorless and tasteless and does not decompose, react chemically, or possess other qualities that would impart flavors to feed. It has no adverse effect on the stability of carotene in alfalfa.

The binding ability of bentonite is especially important where a "hard" pellet is essential in bulk handling operations. Being highly absorptive it is used for the prevention and treatment of "loose droppings." A level of 2 to 2½% of bentonite added to poultry feeds when run through a pellet mill with moisture introduced as steam produces a firm pellet. Since it is a natural lubricant, it helps feed move through dies with a minimum of friction. Sodium bentonite at 2½ to 5% dietary levels significantly reduces the water content of the droppings in both winter and summer. Body weight and egg size are increased. There are no significant effects in egg production but feed efficiency is improved.

Use in Feeds.—A significant increase in growth rate is obtained with the feeding of 2.5% sodium bentonite at an energy level of 770 Cal per lb (454 gm), whereas, when fed in 870 Cal per lb feed, growth was not improved with bentonite. The presence of 3% added fat does not alter the result. A level of 12½% sodium bentonite does not have any detrimental effects on growth rate or feed conversion when fed to chicks for 4-week periods.

Smectite-vermiculite is used in feed in the range of 2 to 10% with optimum levels in the range of 5 to 7%. The product functions favorably in increasing efficiency and improving gains in productivity and in achieving other beneficial effects.

Only limited research has been published on the apparent nutritional effects of kaolins for broilers. Ousterhout (1967) stated that 2½ to 8% kaolin additions to practical broiler feeds improves caloric efficiency with no effect on growth. Added to dilute the practical ration at levels from ½ to 16%, the feeds fed in crushed pellet form were beneficial as shown in Table No. 16.5. Kaolin addition at 5 and 8% improved caloric efficiency 4.9 and 5.7%, respectively, as compared to the control diet. Since the control diet contained 1,500 Cal per lb of metabolizable energy, the results could be interpreted as if the kaolin contained 1,470 and 1,070 Cal. per lb, respectively. Improvement in caloric efficiency was greatest at lower levels of addition, but was still incremental at a diminishing rate as the level of addition increased.

occurs in some geologic deposits. Cadmium is toxic to animals to the same degree as arsenicals, although it is suspected of being able to suppress cholesterol synthesis and also dental caries.

Chromium deficiency symptoms include impaired glucose tolerance, decreased growth and reduced livability. It is related to diabetes and heart disease in some animals. Only trivalent chromium is said to be useful versus the harmful effects of higher valent materials.

Fluorine is regarded as being of major importance since fluoride deficiency has been linked with aging changes seen in osteomalacia. This is not surprising in view of its value against osteoporosis and aortic calcification. It raises the possibility of special value in conditions such as caged layer fatigue and the problem of bone fractures in spent layers at dressing time.

Natural rock phosphate has a high fluorine (3–4%) content which is toxic to poultry. Defluorinated rock phosphate which has had the fluorine reduced ($<0.01\%$) can be used in poultry diets as a source of calcium and phosphorus without problems. Fluorine poisons vital oxidative enzyme reactions in the body by substituting in these reactions for normally used manganese. It is questionable whether this mineral would be of benefit in poultry feeds.

Fluorine toxicity is encountered in poultry in connection with the feeding of natural rock phosphate which has a high fluorine content. Rock phosphate can be defluorinated in various ways and used as a source of calcium and phosphorus without difficulty. Although fluorine has not been shown to be a requirement, poultry are less susceptible to chronic fluorine poisoning than are mammals. Fluorine is deposited in eggs when hens are fed high fluorine rations.

Proteins and Amino Acids

INTRODUCTION—NATURE OF PROTEINS

Proteins are complex compounds that make up a large part of the muscle, skin, feathers, cartilage, beak, and internal organs of birds, and the gluten and germ portions of seeds. They contain about 16% nitrogen and sometimes sulfur, phosphorus, and iron. Protein is needed for growth and the repair of worn-out tissues and to produce antibodies to fight disease. When digested by the bird, they are broken down into component parts, amino acids, which are absorbed and then reassembled into protein in the various tissues of the body.

Proteins are essential in all animal life as components of protoplasm of each living cell. Some plants and bacteria have the ability to synthesize their own proteins from relatively simple compounds such as carbon dioxide, water, nitrates, and sulfates. These forms of life, therefore, are the original sources of the proteins. Protein is the primary constituent of many structural and protective tissues such as bones, ligaments, hair, nails, and skin, as well as the soft tissues of organs. Animals lack the ability to synthesize proteins from simple materials and must depend on plants or other animals as a source of dietary protein. They do have the ability, however, to convert dietary protein into many different and specialized animal proteins. A fairly regular intake of protein is required.

The need for protein actually centers on the amino acids it contains (Table 17.1). Different proteins are characterized by different amounts of particular amino acids. Poultry cannot use efficiently just any mixture; specific amino acids must be provided in proper amounts and in definite ratios to others.

For normal growth, 12 of the amino acids must be in the feed consumed. These are termed "essential" or "indispensable" amino acids. An "essential" amino acid is one which cannot be made in the body or cannot be made in sufficient amounts to meet the body's needs. The "essential" amino acids for laying hens are: phenylalanine, isoleucine, lysine, threonine,. histidine, arginine, tryptophan, methionine, and valine. In addition, the young growing bird also needs glycine and glutamic acid.

The "nonessential" or "dispensable" amino acids may be absent from the feed because chicks can produce them from other amino acids. Actually they are not "nonessential" physiologically; if not present, others must

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be used to form them. In practical rations, nonessential amino acids are provided along with the essential ones, but they are overall amounts rather than at the precise level of essential ones. The sum total of these amino acids demand is the protein requirement.

THE ESSENTIAL AMINO ACIDS

From a practical standpoint, only six amino acids—glycine, arginine, lysine, methionine, cystine, and tryptophan—need special attention in formulation. Others are present in adequate amounts or can be synthesized by the chick, so that a deficiency of one of these would be unlikely.

In spite of the vast number and complexity of proteins, they are split by natural processes into certain element units called the "amino acids." There are 22 recognized amino acids, all of known composition and structures, which make up natural and synthetic proteins. A protein molecule is built up of many hundreds of amino acids combined with each other. Each protein molecule contains many kinds of amino acids. Amono acids in proteins have been compared with the letters of the alphabet which combine in various ways to produce innumerable words, sentences, and paragraphs.

To achieve top performance in poultry production proteins must be balanced with respect to amino acids. Although practical feeds are made up of a variety of ingredients, grains contribute the most weight because they are the best practical sources of energy. Unfortunately, protein quality of grains is poor, so protein ingredients must be added to overcome that deficiency. Only the amount needed to overcome any deficiency in quality is added because protein supplements are more expensive than cereals.

In meeting the requirements for protein, the digestibility of any supplement is considered. If material is not digestible, it is useless to the animal. The nutritional value of a source of protein is affected by its total nitrogen content as well as by its protein quality. Most proteins contain from 14 to 18% of nitrogen with an average of 16%. The protein content of any given feedstuff is estimated by the chemical determination of nitrogen. The percent nitrogen is multiplied by the factor 6.25 which is derived as follows: $\frac{100}{16}$, which is "crude protein" percent. However, methods of processing during the preparation of protein supplements have a substantial effect on their nutritive value. Excessive heating destroys some of the essential amino acids or ties them up in a manner making them unavailable to the birds. However, soybean protein must be properly heated to improve the availability of methionine.

Proteins are from a plant or animal source. Until recently, animal pro-

teins were considered superior to plant proteins because of their better amino acid balance and higher vitamin content. Nevertheless, some plant proteins, notably soybeans and sunflower, are relatively adequate in their amino acid composition. Improvements in the processing of plant proteins eliminates the problem of possible growth inhibitors. Further, many vitamins can be added to feeds in synthetic form at relatively low cost. When the feed is fortified with all of these required nutrients, it can support an excellent rate of growth and egg production without any of the more expensive animal proteins.

The origin of protein is less important than the relationship of its amino acid composition to the nutritional requirements of the bird. Fishmeal and meat meal are excellent feed ingredients but their use is limited because of cost. Relatively pure amino acids have become available from the chemical industry and they are becoming more and more competitive. At the present time only methionine is sufficiently low in price to be practical as an additive. Lysine may become practical where soybean meal is scarce and fishmeal expensive. Synthetic lysine is fairly reasonably priced but is of no practical use in poultry feeds at this time.

There is usually one amino acid which is most effective in satisfying requirements. This is referred to as the "limiting" amino acid. In practical feed formulation, the nutritionist provides adequate amounts of the limiting amino acids either in pure form or by using feedstuffs of higher levels of protein. Usually a combination of protein sources is chosen so that the deficiency in one protein will be overcome by an excess of the same amino *acid in other proteins. The mixture of sources is better nutritionally than a* single source of protein.

Cereal grains which make up the larger portion of feed are universally deficient in lysine. The use of soybean meal, fishmeal, and meat scraps satisfied this lysine need. A rich source of lysine is blood meal, but this is generally unpalatable, except at relatively low levels, and quite imbalanced in other amino acids.

Oil seeds are usually the main source of protein in poultry rations. The limiting amino acid in feeds where soybean meal makes up the main source of protein is methionine which can be corrected by an addition of the synthetic material or by use of protein sources, such as fish meal which are rich in methionine. DL-methionine is frequently added to corn-soy type diets where fishmeals are not included.

Corn, sorghum grains, and barley are deficient in tryptophan as well as lysine; soybean meal, skimmilk or linseed meal corrects this deficiency. Cereal grains are also deficient in arginine, corrected by the use of oil seed meal, fishmeal, or meat scrap. Soybean meal is the high quality, eco-

TABLE 17.1

AMINO ACID CONTENT OF FARM FEEDS

Product	Crude Protein, G per 100 G Product	Arginine, %		Histidine, %		Isoleucine, %		Leucine, %	
		Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein
ALGAE									
Ascomeal	5.75	0.23	4.00	0.064	1.11	0.25	4.35	0.35	6.09
Cladophora rupestris	27.22	1.44	5.29	0.29	1.07	0.94	3.45	1.41	5.18
Laminaria clous toni	10.91	0.25	2.31	0.14	1.28	0.28	2.57	0.39	3.57
Neptune's Bounty	6.01	0.15	2.50	0.052	0.87	0.19	3.16	0.27	4.49
Rhodymenia palmata	20.69	1.08	5.22	0.33	1.59	0.88	4.25	1.12	5.41
ANIMAL BY-PRODUCTS									
Blood meal	80.50	3.37	4.18	4.25	5.28	0.99	1.23	11.10	13.80
Bone meal	23.42	1.77	7.56	0.19	0.81	0.46	1.96	0.97	4.14
Dried buttermilk	30.73	1.06	3.45	0.75	2.44	1.73	5.63	3.01	9.79
Dried cheese whey	12.78	0.32	2.50	0.20	1.56	0.74	5.79	1.14	8.92
Dried skim milk	33.44	1.08	3.23	0.78	2.33	2.00	5.98	3.09	9.23
Dried whey	12.10	0.24	1.98	0.15	1.24	0.74	6.11	1.10	9.09
Meat and bone scraps	52.37	3.79	7.24	0.91	1.74	1.76	3.36	3.27	6.24
Meat scraps									
Sample 1	45.34	3.38	7.46	0.81	1.79	1.48	3.26	2.96	6.53
Sample 2	48.41	3.36	6.94	0.74	1.53	1.50	3.10	3.04	6.28
Tankage	61.02	1.40	2.29	2.05	3.36	1.40	2.29	5.74	9.40
FERMENTATION FEEDS									
Dried brewer's and distiller's grains									
Brewer's dried grains	32.63	1.59	4.87	0.81	2.48	1.66	5.09	3.12	9.56
Distiller's dried grains	26.09	1.09	4.18	0.66	2.53	1.14	4.37	3.14	12.03
Distiller's dried grains with solubles	29.50	1.04	3.53	0.73	2.47	1.19	4.03	2.91	9.86
Corn distiller's dried grains, Distiller's Feed Research Council, composite sample	25.77	1.08	4.19	0.61	2.37	0.94	3.65	2.29	8.89
Corn distiller's dried grains with solubles, Distiller's Feed Research Council, composite sample	27.82	1.12	4.03	0.75	2.70	1.17	4.21	2.95	10.60
Dried fermentation solubles									
Distiller's solubles	27.03	0.96	3.55	0.64	2.37	0.97	3.59	1.61	5.96
Corn distiller's solubles, Distiller's Feed Research Council, composite sample	27.72	1.19	4.29	0.67	2.42	1.13	4.08	2.42	8.73
Corn butyl fermentation solubles	32.13	0.92	2.86	0.52	1.62	1.34	4.17	2.72	8.47
Cane syrup butyl fermentation solubles	25.13	0.47	1.87	0.26	1.03	1.13	4.50	1.30	5.17
Molasses ethyl fermentation solubles (Vacatone 40)	7.85	0.041	0.52	0.037	0.47	0.12	1.53	0.15	1.91
Malt sprouts	29.01	1.25	4.31	0.53	1.83	1.09	3.76	1.64	5.65
Diastatic barley malt	12.28	0.65	5.29	0.29	2.36	0.52	4.23	0.81	6.60
Yeast, Fleishmann's, irradiated, dry	47.38	2.46	5.19	1.00	2.11	2.94	6.20	3.56	7.51
FISH BY-PRODUCTS									
Crab bran	40.05	2.21	5.52	0.80	2.00	1.75	4.37	2.59	6.47
Fish press water	59.72	2.17	3.63	2.02	3.38	0.99	1.66	1.87	3.13
Herring meal	72.25	4.13	5.72	1.71	2.37	4.15	5.74	5.89	8.15
Perch meal	58.42	3.64	6.23	1.14	1.95	2.69	4.60	4.08	6.98
Sardine meal	68.25	4.02	5.89	1.80	2.64	3.48	5.10	5.33	7.81
Shrimp bran	33.44	1.79	5.35	0.67	2.00	1.23	3.68	1.97	5.59
Shrimp meal	42.28	2.25	5.32	0.70	1.66	1.58	3.74	2.27	5.37
Whale meal	53.02	2.50	4.72	1.19	2.24	2.73	5.15	4.29	8.09
White fish meal	67.38	4.38	6.50	1.24	1.84	2.78	4.12	4.48	6.65

TABLE 17.1 (Continued)

AMINO ACID CONTENT OF FARM FEEDS

Lysine, %		Methionine, %		Phenylalanine, %		Threonine, %		Tryptophan, %		Valine, %	
Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein
ALGAE											
0.29	5.04	0.10	1.74	0.28	4.87	0.26	4.52	0.074	1.29	0.31	5.46
1.55	5.69	0.43	1.58	0.96	3.53	1.17	4.30	0.31	1.14	1.23	4.52
0.39	3.57	0.15	1.37	0.29	2.66	0.44	4.03	0.09	0.83	0.47	4.30
0.178	2.96	0.075	1.25	0.21	3.49	0.20	3.33	0.063	1.05	0.24	4.06
1.49	7.20	0.37	1.79	0.81	3.91	0.89	4.30	0.27	1.30	1.25	6.04
ANIMAL BY-PRODUCTS											
3.87	4.81	1.28	1.59	5.80	7.22	4.34	5.39	1.17	1.45	7.76	9.64
0.88	3.76	0.18	0.77	0.56	2.39	0.58	2.48	0.05	0.21	0.72	3.07
2.11	6.86	0.76	2.47	1.44	4.68	1.37	4.46	0.47	1.53	2.11	6.86
1.07	8.37	0.25	1.96	0.36	2.82	0.83	6.50	0.22	1.72	0.73	5.71
2.11	6.31	0.91	2.72	1.73	5.17	1.63	4.87	0.48	1.43	2.29	6.84
0.62	5.12	0.18	1.49	0.29	2.40	0.73	6.03	0.25	2.07	0.67	5.54
2.87	5.48	0.70	1.34	1.79	3.42	1.72	3.28	0.36	0.69	2.50	4.77
2.49	5.49	0.64	1.41	1.73	3.82	1.64	3.62	0.33	0.73	2.38	5.25
2.68	5.54	0.66	1.36	1.64	3.39	1.53	3.16	0.32	0.66	2.17	4.48
4.40	7.21	0.76	1.24	0.78	1.28	2.00	3.28	0.61	1.00	4.18	6.85
FERMENTATION FEEDS											
1.33	4.08	0.65	1.99	1.75	5.36	1.29	3.95	0.37	1.12	1.94	5.95
0.83	3.18	0.56	2.15	1.14	4.37	0.99	3.79	0.23	0.88	1.52	5.83
0.98	3.31	0.64	2.17	1.33	4.51	1 02	3.46	0.24	0.81	1.51	5.12
0.80	3.11	0.49	1.90	1.03	4.00	0.88	3.41	0.22	0.85	1.19	4.62
0.75	2.70	0.60	2.16	1.26	4.53	1.08	3.88	0.23	0.83	1.47	5.28
0.67	2.48	0.48	1.78	1.00	3.70	0.90	3.33	0.22	0.81	1.18	4.37
0.90	3.25	0.55	1.98	1.26	4.55	1.09	3.93	0.25	0.90	1.46	5.27
1.51	4.70	0.49	1.53	1.12	3.49	1.23	3.83	0.24	0.75	1.35	4.20
0.95	3.76	0.41	1.63	0.72	2.87	0.97	3.86	0.19	0.77	1.21	4.81
0.074	0.94	0.057	0.73	0.11	1.40	0.14	1.79	0.03	0.38	0.18	2.29
1.36	4.69	0.39	1.34	0.91	3.14	1.01	3.48	0.41	1.41	1.46	5.03
0.49	3.99	0.18	1.46	0.62	5.05	0.43	3.50	0.22	1.79	0.70	5.70
3.70	7.81	1.00	2.11	2.77	5.85	2.41	5.21	0.73	1.54	3.06	6.46
FISH BY-PRODUCTS											
1.85	4.62	0.73	1.82	1.70	4.25	1.54	3.84	0.45	1.12	2.00	4.99
2.40	4.02	0.80	1.34	0.96	1.61	0.10	0.167	0.17	0.28		
5.92	8.19	2.11	2.92	2.92	4.04	3.26	4.51	1.12	1.55	4.37	6.05
4.39	7.52	1.61	2.76	2.22	3.80	2.46	4.21	0.70	1.20	2.56	4.38
5.86	8.58	2.04	2.99	2.92	4.28	3.04	4.45	0.89	1.30	4.07	5.96
1.48	4.42	0.62	1.85	1.33	3.98	1.34	4.01	0.37	1.11	1.62	4.84
2.02	4.78	0.72	1.70	1.55	3.66	1.47	3.48	0.39	0.92	1.98	4.68
3.49	6.56	1.01	1.90	2.07	3.90	1.64	3.09	0.82	1.55	2.82	5.32
4.57	6.78	1.75	2.60	2.26	3.35	2.76	4.10	0.68	1.01	3.03	4.50

TABLE 17.1 (Continued)

AMINO ACID CONTENT OF FARM FEEDS

Product	Crude Protein, G. per 100 G Product	Arginine, % Sample	Arginine, % Crude protein	Histidine, % Sample	Histidine, % Crude protein	Isoleucine, % Sample	Isoleucine, % Crude protein	Leucine, % Sample	Leucine, % Crude protein
GRAINS									
Barley, Cordona	13.93	0.59	4.24	0.33	2.37	0.57	4.09	0.95	6.82
Barley, Goliad	13.97	0.67	4.80	0.35	2.51	0.52	3.72	0.86	6.16
Buckwheat	11.86	1.13	9.53	0.26	2.19	0.41	3.46	0.62	5.23
Corn, Country Gentleman	11.08	0.45	4.06	0.29	2.62	0.48	4.32	1.55	13.99
Corn, yellow	8.05	0.37	4.60	0.22	2.73	0.33	4.10	0.95	11.80
Darso	8.90	0.36	4.05	0.17	1.91	0.46	5.18	1.30	14.60
Feterita	12.05	0.47	3.90	0.25	2.07	0.62	5.14	1.86	15.40
Hegari	9.94	0.32	3.22	0.19	1.91	0.49	4.94	1.45	14.60
Kafir	11.59	0.44	3.80	0.26	2.24	0.59	5.09	1.75	15.10
Millet, Hog (Proso)	12.14	0.35	2.89	0.23	1.90	0.49	4.04	1.23	10.13
Milo, Martin	10.25	0.45	4.39	0.22	2.15	0.46	4.49	1.22	11.90
Oats, Alamo	12.15	0.87	7.16	0.26	2.14	0.55	4.53	0.85	7.00
Oats, Fultex	8.98	0.64	7.10	0.19	2.11	0.39	4.33	0.63	7.01
Oats, Mustang	11.60	0.57	4.91	0.20	1.72	0.45	3.88	0.74	6.38
Oats, Ranger	10.45	0.74	7.08	0.20	1.91	0.46	4.40	0.72	6.89
Rice, Early prolific	6.39	0.54	8.44	0.14	2.19	0.28	4.38	0.51	7.98
Rice, Texas Patna	7.84	0.65	8.29	0.18	2.30	0.36	4.59	0.62	7.91
Rice, Texas Patna, Polished	7.88	0.65	8.25	0.19	2.41	0.35	4.44	0.63	7.99
Rye	11.19	0.59	5.27	0.25	2.23	0.43	3.84	0.67	5.99
Shallu	8.23	0.34	4.13	0.19	2.31	0.40	4.87	1.04	12.70
Speltz	9.56	0.46	4.81	0.20	2.09	0.42	4.39	0.67	7.01
Wheat, Austin	11.15	0.55	4.93	0.26	2.33	0.44	6.91	0.80	7.17
Wheat, Frisco	15.28	0.81	5.30	0.38	2.49	0.61	3.99	0.96	6.28
Wheat, Quanah	18.16	0.86	4.74	0.44	2.42	0.77	4.24	1.21	6.66
Wheat, Seabreeze	18.50	1.01	5.46	0.50	2.70	0.71	3.84	1.13	6.11
Wheat, Selkirk	17.00	0.83	4.88	0.48	2.82	0.60	3.53	1.05	6.18
GRAIN BY-PRODUCTS FROM MILLING AND PROCESSING									
Corn by-products									
Corn meal, yellow	9.34	0.45	4.82	0.24	2.57	0.36	3.85	1.12	12.00
Corn gluten meal	45.72	1.50	3.28	1.00	2.19	2.03	4.44	7.53	16.47
Corn gluten feed	22.86	0.98	4.29	0.69	3.02	0.81	3.54	2.34	10.23
Corn oil cake meal (germ meal)									
Sample 1	22.16	1.39	6.27	0.67	3.02	0.86	3.88	1.82	8.21
Sample 2	22.69	1.51	6.65	0.78	3.44	0.96	4.23	1.97	8.68
Hominy, yellow	10.56	0.61	5.78	0.29	2.75	0.43	4.07	1.17	11.08
Grain sorghum by-products									
Grain sorghum oil cake meal (germ meal)									
Sample 1	21.62	1.48	6.84	0.73	3.38	0.98	4.53	1.88	8.70
Sample 2	18.50	1.05	5.68	0.64	3.46	0.78	4.22	1.45	7.84
Grain sorghum gluten feed	22.26	0.95	4.27	0.61	2.74	0.98	4.40	2.53	11.37
Grain sorghum gluten meal									
Sample 1	44.54	1.19	2.67	0.81	1.82	2.26	5.07	7.30	16.39
Sample 2	64.69	1.38	2.13	1.09	1.68	3.28	5.07	11.11	17.17
Milo heavy steep water 54.7% solids	17.82	1.58	8.87	0.64	3.61	0.33	1.85	0.62	3.46
Oatmeal	14.76	0.99	6.71	0.31	2.10	0.63	4.27	1.14	7.72
Rice by-products									
Rice bran	12.54	1.07	8.53	0.35	2.79	0.55	4.38	0.89	7.10
Rice, polish	12.78	1.04	8.14	0.32	2.50	0.44	3.44	0.81	6.34
Wheat by-products									
Wheat bran	14.58	1.09	7.48	0.44	3.02	0.54	3.70	0.92	6.31
Wheat germ meal	28.08	2.08	7.41	0.64	2.28	0.97	3.45	1.67	5.95
Wheat grey shorts	15.88	0.96	6.04	0.36	2.27	0.58	3.65	0.93	5.86
Wheat, Red Dog	14.22	0.55	3.87	0.29	2.04	0.59	4.15	1.02	7.17
Wheat shorts	16.85	1.07	6.35	0.48	2.85	0.63	3.74	1.03	6.11

TABLE 17.1 (Continued)

AMINO ACID CONTENT OF FARM FEEDS

Lysine, %		Methionine, %		Phenylalanine, %		Threonine, %		Tryptophan, %		Valine, %	
Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein
GRAINS											
0.48	3.45	0.20	1.44	0.77	5.53	0.48	3.45	0.178	1.28	0.76	5.45
0.51	3.65	0.18	1.29	0.67	4.80	0.47	3.36	0.177	1.27	0.70	5.01
0.66	5.56	0.22	1.85	0.45	3.79	0.50	4.22	0.200	1.68	0.56	4.72
0.33	2.98	0.21	1.90	0.55	4.97	0.39	3.52	0.089	0.80	0.59	5.32
0.27	3.35	0.18	2.24	0.42	5.22	0.31	3.85	0.087	1.17	0.43	5.34
0.19	2.14	0.13	1.46	0.51	5.73	0.34	3.82	0.122	1.37	0.51	5.73
0.23	1.91	0.19	1.58	0.72	5.98	0.47	3.90	0.159	1.32	0.71	5.89
0.17	1.71	0.14	1.41	0.55	5.53	0.37	3.72	0.122	1.23	0.56	5.63
0.25	2.16	0.21	1.81	0.66	5.70	0.46	3.97	0.150	1.30	0.66	5.69
0.25	2.06	0.30	2.47	0.59	4.86	0.44	3.63	0.168	1.38	0.62	5.12
0.24	2.34	0.18	1.75	0.50	4.88	0.41	4.00	0.140	1.36	0.58	5.66
0.53	4.36	0.16	1.32	0.59	4.86	0.47	3.87	0.173	1.42	0.70	5.76
0.43	4.78	0.14	1.56	0.44	4.90	0.36	4.00	0.103	1.15	0.53	5.89
0.38	3.28	0.10	0.83	0.51	4.40	0.38	3.28	0.156	1.34	0.60	5.17
0.41	3.92	0.12	1.15	0.53	5.07	0.39	3.72	0.155	1.48	0.61	5.84
0.28	4.38	0.14	2.19	0.31	4.85	0.22	3.44	0.098	1.53	0.40	6.26
0.31	3.96	0.18	2.30	0.38	4.87	0.28	3.57	0.125	1.59	0.50	6.38
0.26	3.30	0.20	2.54	0.36	4.57	0.27	3.43	0.125	1.59	0.50	6.34
0.45	4.02	0.18	1.61	0.47	4.20	0.37	3.31	0.140	1.25	0.56	5.00
0.20	2.43	0.15	1.82	0.43	5.23	0.33	4.01	0.101	1.23	0.46	5.59
0.29	3.03	0.16	1.67	0.46	4.81	0.38	3.97	0.122	1.28	0.47	4.92
0.32	2.87	0.17	1.52	0.57	5.11	0.42	3.77	0.180	1.61	0.52	4.66
0.41	2.68	0.19	1.24	0.72	4.71	0.45	2.95	0.241	1.58	0.69	4.52
0.50	2.75	0.24	1.32	0.88	4.85	0.46	2.53	0.230	1.27	0.71	3.91
0.50	2.70	0.23	1.24	0.90	4.86	0.53	2.86	0.224	1.21	0.85	4.61
0.43	2.53	0.22	1.29	0.86	5.06	0.52	3.06	0.249	1.46	0.78	4.59
GRAIN BY-PRODUCTS FROM MILLING AND PROCESSING											
0.29	3.10	0.21	2.25	0.41	4.39	0.34	3.64	0.082	0.90	0.50	5.36
0.96	2.10	1.22	2.67	2.80	6.12	1.63	3.56	0.24	0.52	2.37	5.18
0.74	3.24	0.48	2.10	0.87	3.80	0.81	3.54	0.16	0.70	1.26	5.51
1.05	4.74	0.44	1.98	0.91	4.11	0.86	3.88	0.23	1.04	1.31	5.91
1.19	5.24	0.43	1.90	0.95	4.19	0.94	4.14	0.29	1.28	1.50	6.61
0.46	4.36	0.20	1.89	0.48	4.54	0.43	4.07	0.12	1.14	0.60	5.68
0.86	3.98	0.35	1.62	1.00	4.62	0.74	3.42	0.22	1.02	1.44	6.66
0.71	3.82	0.29	1.57	0.75	4.03	0.77	4.15	0.21	1.16	1.15	6.22
0.67	3.01	0.37	1.66	1.02	4.58	0.80	3.59	0.19	0.85	1.29	5.80
0.59	1.32	0.72	1.62	2.58	5.79	1.34	3.01	0.45	1.01	2.52	5.66
0.70	1.08	0.97	1.50	3.64	5.63	1.97	3.05	0.76	1.17	2.45	3.79
0.45	2.53	0.42	2.35	0.31	1.72	0.95	5.33	0.124	0.70	1.08	6.06
0.62	4.20	0.25	1.69	0.78	5.28	0.48	3.25	0.23	1.56	0.86	5.83
0.67	5.34	0.24	1.91	0.58	4.62	0.49	3.91	0.24	1.91	0.75	5.98
0.64	5.01	0.21	1.64	0.48	3.76	0.45	3.52	0.19	1.49	0.75	5.87
0.64	4.39	0.24	1.65	0.55	3.77	0.52	3.57	0.41	2.81	0.81	5.56
1.84	6.55	0.46	1.64	1.11	3.96	1.11	3.95	0.30	1.07	1.41	5.02
0.66	4.16	0.24	1.51	0.57	3.59	0.49	3.08	0.30	1.89	0.78	4.91
0.31	2.18	0.22	1.55	0.66	4.64	0.40	2.81	0.22	1.55	0.63	4.43
0.68	4.04	0.30	1.78	0.65	3.86	0.59	3.50	0.27	1.60	0.87	5.16

TABLE 17.1 (Continued)

AMINO ACID CONTENT OF FARM FEEDS

Product	Crude Protein, G. per 100 G. Product	Arginine, %		Histidine, %		Isoleucine, %		Leucine, %	
		Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein
OIL SEED RESIDUES									
Babassu meal	22.72	3.19	14.04	0.41	1.81	0.88	3.87	1.40	6.17
Castor flour	65.03	8.39	12.90	1.36	2.09	3.46	5.32	4.16	6.40
Castor pomace	39.79	3.99	10.03	0.67	1.68	1.85	4.65	2.25	5.65
Copra meal	22.22	2.54	11.43	0.38	1.71	0.89	4.00	1.40	6.30
Cottonseed meal	39.61	4.38	11.02	1.07	2.70	1.59	4.01	2.46	6.20
Cottonseed flour (Proflo)	54.07	6.11	11.30	1.39	2.57	2.13	3.94	3.37	6.23
Linseed meal	36.73	3.41	9.28	0.66	1.80	1.68	4.57	2.19	5.96
Palm kernel meal	19.16	2.54	13.26	0.31	1.62	0.76	3.97	1.23	6.42
Peanut meal	38.95	4.02	10.33	0.84	2.16	1.69	4.33	2.60	6.68
Peanut flour	61.00	6.87	11.26	1.32	2.16	2.64	4.33	4.11	6.74
Safflower meal	22.10	1.72	7.78	0.44	1.99	0.85	3.85	1.22	5.52
Sesamine meal	46.08	5.49	11.91	1.02	2.21	1.97	4.27	3.19	6.92
Soybean meal	45.29	3.38	7.46	1.12	2.49	2.49	5.50	3.48	7.69
Soybean protein (commercial)	79.50	5.72	7.20	1.85	2.33	4.65	5.85	6.18	7.77
Sunflower seed meal	21.02	1.63	7.76	0.46	2.19	0.95	4.52	1.25	5.95
Tung meal	20.88	2.27	10.87	0.48	2.30	1.03	4.93	1.58	7.57
Walnut oil meal	13.03	0.97	7.44	0.21	1.61	0.42	3.22	0.68	5.22
PEAS AND BEANS									
Black-eye peas	22.31	1.43	6.41	0.63	2.82	1.03	4.62	1.61	7.22
Cow peas, mixed	24.14	1.27	5.27	0.73	3.03	1.14	4.72	1.73	7.17
Mexican Pinto beans	22.58	1.55	6.85	0.64	2.83	1.14	5.05	1.11	4.92
Soybeans, Laredo	35.02	2.40	6.84	0.80	2.29	1.88	4.68	2.03	5.80
Soybeans, Arksay	39.77	2.95	7.42	0.90	2.26	2.13	5.36	3.05	7.68
Soybeans, Red Tanner	42.08	3.27	7.78	1.00	2.39	2.21	5.26	3.24	7.71
MISCELLANEOUS									
Alfalfa leaf meal	19.47	0.96	4.93	0.42	2.18	1.00	5.14	1.54	7.91
Animal protein factor[a]	52.94	1.98	3.74	0.49	0.93	1.58	2.98	1.79	3.38
Antibiotic feed supplement[b]	46.13	1.27	2.75	0.98	2.12	1.98	4.29	1.80	3.90
Citrous pulp	5.82	0.28	4.81	0.09	1.55	0.18	3.10	0.31	5.33
Coffee pulp	10.59	0.38	3.68	0.21	1.98	0.40	3.78	0.58	5.48
Cow pea foliage, dry	26.01	1.11	4.27	0.45	1.73	1.26	4.84	2.00	7.69
Gourd seed meal *C. foetidissima*	63.50	9.05	14.25	1.18	1.86	2.78	4.38	4.22	6.65
Pumpkin seed	30.81	3.39	11.00	0.65	2.10	1.12	3.64	1.65	5.37
Sweet potato stock feed	3.88	0.094	2.42	0.061	1.57	0.20	5.15	0.27	6.96

[a] Dried fermentation product prepared as source of vitamin B_{12}. Amino acid composition of products is due to the carrier substance. Other animal protein factor preparations may be quite different in amino acid content according to the process used.

[b] Dried fermentation by-product from bacitracin production.

nomical ingredient which balances cereal grains most effectively with regard to essential amino acids. Both 44% and 50% protein soybean meals are available.

PROTEIN REQUIREMENTS

The protein requirement of poultry is usually stated as a percentage of the diet. This is affected by the energy content and the quality of the protein of the ration. Poultry stop eating when their energy requirements are

TABLE 17.1 (Continued)

AMINO ACID CONTENT OF FARM FEEDS

Lysine, %		Methionine, %		Phenylalanine, %		Threonine, %		Tryptophan, %		Valine, %	
Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein	Sample	Crude protein
OIL SEED RESIDUES											
0.98	4.31	0.53	2.33	1.35	5.94	0.71	3.13	0.24	1.06	1.19	5.24
2.20	3.38	1.16	1.78	3.38	5.19	2.50	3.84	0.93	1.43	4.38	6.74
0.12	3.02	0.58	1.46	1.86	4.68	1.29	3.24	0.44	1.11	2.15	5.40
0.68	3.06	0.35	1.59	0.94	4.23	0.84	3.78	0.21	0.94	1.22	5.49
1.67	4.20	0.59	1.49	2.09	5.25	1.38	3.47	0.63	1.59	1.98	4.98
2.25	4.16	0.87	1.61	2.81	5.20	1.82	3.36	0.84	1.55	2.62	4.84
1.33	3.62	0.61	1.66	1.65	4.49	1.39	3.78	0.64	1.74	2.04	5.55
0.66	3.44	0.41	2.14	0.82	4.28	0.60	3.13	0.20	1.04	1.03	5.38
1.38	3.53	0.41	1.04	1.94	4.97	1.16	2.98	0.47	1.22	1.88	4.82
1.95	3.20	0.62	1.02	3 10	5.08	1.63	2.67	0.78	1.28	2.83	4.64
0.60	2.71	*0.34*	*1.54*	*1.16*	5.25	*0.65*	2.94	*0.26*	*1.18*	*1.09*	4.93
1.27	2.76	1.22	2.65	2.18	4.73	1.68	3.64	0.88	1.91	2.33	5.06
2.79	6.17	0.63	1.39	2.20	4.86	1.82	4.03	0.76	1.69	2.45	5.40
4.59	5.77	0.93	1.17	4.40	5.53	2.83	3.56	1.16	1.46	4.09	5.14
0.80	3.81	0.46	2.19	1.76	5.12	0.72	3.43	0.29	1.38	1.03	4.90
0.87	4.17	0.47	2.24	1.52	7.28	0.96	4 60	0.35	1.68	1.74	8.33
0.28	2.15	0.16	1.23	0.43	3.30	0.34	2.61	0.20	1.53	0.50	3.82
PEAS AND BEANS											
1.47	6.59	0.34	1.52	1.20	5.38	0.80	3.58	0.23	1.03	1.18	5.29
1.52	6.30	0.28	1.16	1.25	5.18	1 04	4.31	0.32	1.33	1.34	5.56
1.60	7.08	0.26	1.15	1.20	5.31	1.09	4.82	0.32	1.42	1.23	5.54
2.26	6.47	0.48	1.37	1.67	4.77	1.29	3.68	0.56	1.60	1.89	5.39
2.68	6.73	0.62	1.57	2.07	5.20	1.57	3.96	0.56	1.42	2.06	5.18
2.64	6.28	0.54	1.28	2.14	5.08	1.57	3.73	0.56	1 33	2.30	5.46
MISCELLANEOUS											
1.08	5.55	0.30	1.54	0.99	5.08	0.90	4.62	0.41	2.11	1.10	5.65
1.63	*3.08*	0.40	*0.76*	*1.04*	*1.96*	1.49	2.81	*0.31*	0.59	*1.67*	*3.15*
2.08	4.51	0.45	0.98	1.67	3.62	0.95	2.06	0.40	0.87	1.20	2.60
0.20	3.44	0.08	1.37	0.18	3.09	0.18	3.09	0.06	1.03	0.25	4.30
0.36	3.40	0.28	2.64	0.33	3.12	0.33	3.12	0.10	0.94	0.50	4.72
1.08	4.15	0.51	1.96	1.25	4.81	1.06	4.08	0.52	2.00	1.43	5.50
2.07	3.26	1.23	1.94	2.91	4.58	1.65	2.60	1.02	1.61	3.05	4.80
1.56	*5.06*	*0.63*	*2.06*	*1.32*	*4.28*	*0.72*	*2.34*	*0.46*	*1.49*	*1.30*	*4.21*
0.076	1.96	0.08	2.06	0.20	5.15	0.18	4.64	0.069	1.78	0.25	6.44

satisfied. The intake of energy, therefore, determines the consumption of protein, as well as other nutrients. When the energy content of the feed is increased, protein level must be raised, as must the levels of other essential nutrients. High-energy, high-protein feeds are not necessarily the most economical per unit of production. The latter depends largely on the relative cost of high-energy ingredients, especially fats compared with the protein supplements of cereal grains. When high-energy, high-protein ingredients are relatively inexpensive, it is possible to increase the energy content of the diet along with protein.

Since poultry reduce their feed intake in periods of illness, thus lowering the intake of all essential nutrients, is is necessary to fortify the feed

with vitamins and proteins so that the reduced feed intake will not cause a deficiency in these other nutrients.

Birds grow only if given those amino acids listed as indispensable. If there are not enough dispensable amino acids, the indispensable ones will be used for less important ones.

CORRECTING AMINO ACID DEFICIENCIES

There are three ways of correcting an amino acid deficiency: (1) add the missing amino acid in pure form, except for methionine, this is usually too expensive in practical feeds; (2) feed a higher percentage of protein in the diet, this is usually impractical and wasteful of protein; (3) use a combination of proteins so that the shortcomings of one protein is compensated by an abundance of a certain required amino acid in the other proteins. This is most practical. For example, casein and gelatin alone are not adequate proteins for the chick but a mixture of the two proteins support good growth, since each compensates for certain deficiencies of the other.

Proteins or amino acids consumed in excess of the animal's requirement are not stored as some vitamins are. They are disposed of quickly by conversion to carbohydrates and energy or by excretion. For greatest economy, however, an attempt should be made to achieve a combination of proteins which will be complete as possible in amino acids at a minimum total percentage of protein in the diet.

"Biological value" of protein is a measure of protein retention by poultry during a rigorously defined procedure. This required feeding tests with supplementary proteins and amino acids and some knowledge of the amino acid composition of the protein, but does not identify a particular deficiency.

The Five Critical Amino Acids

A comparison of the chicks requirement with the average amino acids in feedstuff proteins shows that only arginine, lysine, methionine, cystine, and tryptophan need particular attention in practical rations. All other amino acids are readily synthesized or present in ample quantity. Knowing the requirements of the chick and the amino acid composition of the protein carrier, one can estimate the adequacy of that protein carrier as a source of amino acids for the young chick. The five critical amino acids indicate how each feedstuff protein measures up to the average requirement of the chick. Chicks grow at an optimum rate regardless of the name or nature of the concentrate being fed so long as that concentrate is readily digested and provides the fundamental amino acid requirement of the chick.

High quality fishmeal is a complete source of amino acids on the basis of analytical data and will support normal chick growth entirely by itself. Meat scraps give a surplus of glycine and arginine and has a deficiency in the sulfur amino acids and tryptophan. Milk proteins are deficient in glycine

and arginine for the chick, but are good sources of lysine and tryptophan. Soybean protein is complete except for sulfur containing amino acids. The most common deficiency among other oil cake meals is that of lysine. Cereal proteins are uniformly weak sources of lysine but their use is unavoidable.

Terms like animal protein and vegetable protein have been replaced by considerations of the amino acid composition of the feedstuff proteins, *irrespective of their origin. One serious amino acid deficiency is enough to* cause a failure of the entire diet. It makes little difference whether it is 1 deficiency or 6. Egg proteins contain more of the sulfur amino acids, methionine and cystine, and this would seem to indicate that for optimal production, hens need a generous supply of methionine and cystine.

The hen has a high sulfur amino acid requirement during the molting period. Feathers are rich in cystine. Sulfur amino acids will not shorten the molting period but help bring the hen through it in better condition due to less depletion of its body protein. In feed formulation, avoid a serious deficiency of required amino acids and a wasteful surplus of amino acids. The proportion of amino acid to total protein for optimum results changes *with the protein level. The relative proportions of indispensable amino acids* in the diet are more important than the protein level. Chicks and poults divert large portions of their sulfur amino acid intake to the rapid growth of feathers which contain 10% cystine. A rapidly feathering breed (Leghorn) shows a marked growth in feather response to arginine and glycine supplements, while a slowly feathering breed (Plymouth Rock) show less response. Rate of feather formation is a factor in arginine and glycine requirements of young birds.

THE PROTEIN LEVEL AND DISEASE RESISTANCE

The relation of protein level to disease resistance deserves mention because immunity is largely concerned with proteins. Elements in the bloodstream which resist disease—blood cells, blood globulins, antibodies, and complement are protein in nature. Animals which are depleted of protein are less resistant to infections and have a lowered ability to recover from disease. Enzymes which are necessary to utilize food, are mainly proteins. Proteins and amino acids are interrelated with vitamins. Tryptophan is used by chicks to produce niacin; either will help to overcome a niacin deficiency. Excess levels of some amino acids are harmful. These effects are more acute under niacin deficiency conditions. An incomplete conversion of tryptophan to niacin occurs in vitamin B-complex deficiency. In fact, many vitamins are closely connected with general amino acid utilization. Riboflavin bears a definite relation to retention and metabolism of protein, and folic acid is required.

A well known interrelationship occurs between methionine and choline in

which methionine furnishes the methyl group for choline synthesis. Severe overheating of protein meals, such as fish, meat, and casein which contain little or no free carbohydrate, causes the amino acid lysine and possibly arginine and histidine to become tied up by new chemical linkages to other amino acids which reduce their availability to enzymes and the animal. The overheating of proteins in contact with carbohydrates causes a nutritional destruction of amino acids through the reaction with carbohydrates. Those particularly attacked include arginine, lysine, and tryptophan. This loss occurs in overheated soybean meal. Lysine is attacked most readily. Heating, cooking, and drying of protein meals in modern equipment do not seriously impair relative availability of amino acids with the possible exception of cystine which is not indispensable but of actual value in sparing methionine.

THE NATURE OF PROTEIN

Supplements are used in feeds primarily on their "crude protein" content. The chemical determination of protein is not for protein as such but of the combined nitrogen content which averages 16%. Unfortunately, the combined nitrogen is not all protein or amino acid in nature. Aside from amino acid composition, there are features such as lack of digestibility, decomposition and nonprotein nitrogen forms of nitrogen which determine protein quality and utilization. It is unlikely that any physiological process can be carried out in living animals without the involvement of protein. By contrast, nonnitrogenous foods such as the carbohydrates and fats function in the body chiefly as sources of energy required for body warmth, physical work, and for this purpose proteins, serve equally as well. Birds synthesize both carbohydrates and fats from proteins.

While proteins have many properties in common, they do not all contain exactly the same relative proportions of carbon, hydrogen, and nitrogen, yield exactly the same substances when digested, nor are they equally efficient in nutritional value. Through the action of digestive enzymes (pepsin in the stomach and trypsin in the small intestine) proteins are broken down into a number of simpler nitrogen compounds, amino acids. A single complex protein molecule may yield as many as a thousand of the simpler amino acid molecules. Possibly 80 different kinds of amino acids exist in nature, of which 24 are degradation products. Nearly all feed proteins yield about 20 kinds of these acids in different proportions. Some like gelatin yield only 14 or 15; simpler proteins only 3 or 4. All of the amino acids occurring in feed proteins are now available in the purified state; some from feed proteins and others from synthetic sources. With the exception of glycine, they occur in two optically active forms—levorotary and the dextrorotary. The levorotary form occurs in natural proteins and is the only

form utilizable by animals. Synthetic amino acids are usually mixtures of both forms and in equal proportions. Amino acids are soluble in water. After absorption through the intestinal walls into the blood stream, they are carried to all parts of the body where they are recombined to form new proteins. Each body cell takes from the blood the kind and number of amino acids needed to form the kind of protein peculiar to it. Excess amino acids not needed for formation of body proteins are split by the liver into still simpler nitrogen compounds which are eliminated from the body through the urine, and a carbohydrate residue which is utilized as a source of energy. Chicks and poults that double their body weight every few days require rations supplying higher levels of protein in early life than in later stages of growth. Also, they should be fed more frequently.

Biological Value of Proteins

The term "biological value" was first applied to proteins in 1911 by Carl Thomas, a German physiologist. Differences in biological value are explainable on the basis of differences in essential amino acid content. For monogastric animals like the chicken, the protein requirement will vary widely depending on the biological value of the proteins in the ration. The more similar the makeup of dietary protein is to the makeup of the body proteins, the lower the requirement. The amino acid content of proteins is of less importance to ruminants than to nonruminants due to the protein synthesis by rumen bacteria. An excess of protein can be fed without detriment to the health of birds.

Certain oilseed meals contain nonprotein factors which have been shown to be detrimental, but if these meals are processed correctly, there is no danger from high percentages of these products. Since proteins are generally more expensive than carbohydrates and fats, there is usually no incentive in supplying more protein than the minimum requirements for optimum performance.

Lysine is the most limiting amino acid in the protein of all the grains. Tryptophan and arginine are the next most limiting amino acids in corn protein. Arginine is the second limiting amino acid in milo protein while threonine, methionine, arginine, and valine are the next limiting amino acids in wheat protein. Peanut meal is deficient in methionine, lysine, and threonine. Plant breeders have found that a mutant gene called "opaque-2" increases the lysine level in corn protein.

A decade or so ago high-energy, high-efficiency rations were introduced for accelerating the rate of growth of broilers. When energy was increased by decreasing fibrous materials, such as bran and wheat middlings, and adding fat, improved performance resulted. On a weight basis, fat has approximately twice the energy value of carbohydrates.

Thus, the proteins stand at the center of all forms of life and it is through them that the chief phenomena are produced. Less than ⅓ of the protein in rations fed chicks and poults is grain protein, but ½ to ⅔ of the protein in rations fed to older birds may come from grains. Grains, in general, do not contain high quality proteins from a nutritional standpoint. The amount of lysine and methionine supplied by a grain protein is important because so many of the available protein supplements are deficient in these amino acids.

In practical diets with moderate supplemental levels of methionine, there is usually no demonstrable difference in the potency of methionine isomers for growth promotion. The hydroxy analog shows a potency which is approximately the same as that of an equivalent molecular level of DL-methionine. Feed conversion effects are, in general, consistent with the growth effects. The general functions of methionine involve interactions with other molecular species.

Effects of Protein Deficiencies

It has long been observed that animals receiving feed deficient in certain nutrients crave things to eat and consume a wide variety of things if available. Under certain conditions poultry consume litter, molted feathers, and other, and develop the vice of picking or cannibalism. Partial molting of pullets takes place during their growing period and feathers accumulate in the litter if the birds are fed an adequate ration. The fact that feather accumulation does not happen in certain experiments indicates that the rations may be deficient in protein, more specifically methionine. The presence or absence of molted feathers in pens can be related to nutritional variables in rations of growing pullets. Inadequate protein or methionine levels cause relatively feather-free pens and reduced body weights due to the eating of the molted feathers. Thus, the accumulation of molted feathers in a pullet-rearing house is a good omen, an indication that birds are receiving an adequate protein ration.

Most researchers believe that the total protein level of a diet has little nutritional significance. There is, of course, a requirement for total nitrogen, but not all of this must be furnished in the form of essential amino acids. The quantities and balance of the essential amino acids are vital requirements as variations in biological value of protein can be explained fully by them. The chief problem concerns determining the availability of amino acids in a protein source. Amino acid analyzers based on chromatography are in general use, but feeding tests are necessary to assure that what is being measured is that which is required by the animal.

AMINO ACID REQUIREMENTS OF POULTRY

The amino acid requirements of poultry should be based on daily intake, not as a percentage of the diet. Many factors modify requirements: growth

rate, body size, egg production, body composition, genetics, and environmental temperature. Formulas proposed for calculating requirements are based upon a restricted set of conditions. Amino acid balance involves relationships with other nutrients. Increasing the energy content of the broiler ration without also increasing the protein content actually results in less growth. When both protein and energy are increased, expected improvement in performance is obtained. Another consideration is balance between essential amino acids. An indiscriminate increase in protein is not a good way to improve amino acid balance. To meet accurately requirements, one must know quantitative needs and exact composition of the available feed ingredients.

For supplementation of a typical corn-soybean meal ration for poultry, the first limiting amino acid is methionine; the second is lysine. A further problem concerns digestibility and utilization of ingredients. In other words, how much of the essential amino acids are actually available to the birds? Feeding values of protein cannot be clearly determined by any chemical tests, although they are helpful to a degree. There is increasing emphasis on amino acid supplementation as a single most effective way of achieving

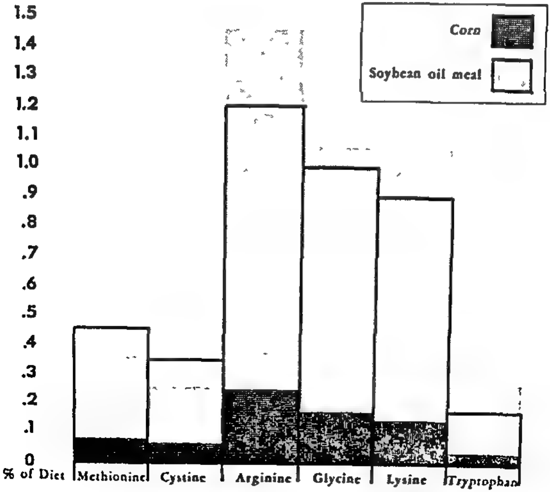


FIG. 17.1. AMINO ACID SUPPLEMENTATION

essential protein balance. Simple manipulation of protein feedstuffs in the diet cannot assure both fulfillment of amino acid requirement necessary for optimum growth and most efficient utilization of these feedstuffs.

Ingredients used in rations are varied in number and proportion. High-cost animal sources, such as fishmeal, may satisfy amino acid requirements but the cost per ton of ration would be prohibitive. On the other hand, low-cost protein sources, such as soybean meal, cost less per pound but fail to satisfy all essential requirements, particularly those of methionine and cystine so necessary for chick development. The answer to efficient, economically balanced feeds of the high energy type lies in the addition of single sources of amino acids. Only in this way can a formulator balance out the amino acid patterns of protein feedstuffs for optimum efficiency as well as maximum rate of growth.

FEED FORMULATIONS

Formulating efficient feeds demands that the amino acid requirements for both the caloric and protein level of the diet be met in full. Protein feedstuffs cannot meet all the amino acid requirements efficiently. Synthetic supplements are necessary for economic, efficient balancing and are increasingly important in overcoming deficiencies of the two sulfur containing amino acids, methionine and cystine.

Feed manufacturers should secure at frequent intervals an analysis of the feed ingredients used in their mill. The average composition of these ingredients can be used in formulating rations by linear programming techniques. Although there is insufficient information on digestibility of the various ingredients, this information is needed to formulate equations in linear programming to secure least-cost rations. No single feed ingredient supplies the essential amino acids in exactly the right balance. Yellow corn has less than ½ enough protein and only about ⅓ enough arginine, glycine, and lysine. If we combined corn and soybean oil meal to make up 95% of a hypothetical protein broiler mash, leaving 5% for mineral and vitamin supplements, the methionine-cystine are the limiting amino acids, and there will be 3.7% of ineffective protein. In a more complex ration of alfalfa meal, corn gluten meal, fishmeal, meat meal, distillers solubles, dried whey and fish solubles, glycine is the most limiting amino acid, with methionine-cystine combination a close second. The difficulty of balancing 13 variables by putting together different combinations of all 13 is obvious. The easy way to reach amino acid balance is to add individually those that are needed. Attention must be given to methods of improving protein utilization. Once a synthetic amino acid has already proved its value in practical feeds, probably others will follow.

On the whole, proteins from plant materials are of lower quality or

nutritional values than animal proteins, as has been shown by numerous growth studies. The low lysine, methionine, and tryptophan contents of the protein in bone meal confirms the generally accepted conclusion that the protein of this product is of low nutritional value. Fish by-products are good sources of lysine—particularly herring, perch, sardine, and white-fish meals. Grains, in general, have a lysine deficiency—particularly serious in wheat and grain sorghums, but less so in oats. Buckwheat, however, has a relatively high lysine content. Yellow corn and hard millet has the highest percentage of methionine in their proteins. Grains, in general, are not tryptophan deficient. Germ proteins of corn, wheat, and grain sorghums are higher in lysine than the whole seed from which they are obtained. In contrast, corn gluten and grain sorghum gluten are products of low lysine content. Corn gluten is an outstanding source of methionine but is low in tryptophan and lysine. Fermentation feeds are deficient in lysine as are the grains from which they are made. They are moderately deficient in tryptophan for the chick. Soybean meal has a relatively high content of lysine but only part of the lysine in cottonseed meal is available. The oilseed meals contain some good sources of methionine. These include babassu, palm kernel, sesame, and sunflower seed meals which are good sources of tryptophan. Peas and beans have a relatively high lysine content and are good sources of tryptophan. The high lysine content of yeast is of interest.

A world deficiency of animal proteins exists which will become more serious as population increases. More and more of the required feed protein must be supplied by plant proteins. As more information becomes available on the amino acid composition of plant proteins, better use will be made of those now available for it will then be possible to combine them so as to satisfy requirements more efficiently and economically.

PROTEIN REQUIREMENTS OF LAYING HENS

The laying hen puts 6.2–6.7 gm of protein into each egg and requires 3.0 to 3.3 gm of protein per day for maintenance of her body tissues. The laying hen, however in practice, consumes 18 gm of protein per day in order to achieve good egg production. The question arises why the hen consumes this amount of protein when she makes use of only about 10 gm. The first possibility is that the feed protein is highly indigestible and the hen utilizes only 55% of the protein of the feed. Yet, tests indicate that the hen actually digests and absorbs 85% of the protein in the diet. The answer must lie then in the lack of efficient utilization of dietary protein for egg production due to an imbalance of the amino acids required. The hen must consume about 12.2 gm of feed protein in order to get sufficient methionine to put into an egg containing 6.1% of egg protein. Theoretically, it should be possible to reduce the amount of protein that must be consumed by the hen in order to

make an egg by addition of methionine to the laying ration. If one should add the amount of methionine required to reduce the amount of needed feed proteins to 9.7 gm, then the total protein intake needed by the hen should be only 15 gm per day. Under these conditions, the hens would not need to overeat in order to obtain the amino acids required for the formation of an egg and, therefore, could produce eggs with a better efficiency of feed utilization.

The minimum protein requirement can only be achieved when the diet provides sufficient energy from carbohydrates and fat such that the hen can make the most efficient use of the protein in the diet. Such a balance produces better feathering and health, prevents wet litter, and makes for better efficiency of feed utilization by the hens. Since feathers are high in sulfur amino acids, their formation undoubtedly causes a drain on methionine available for other functions such as maintenance of muscle tissue and production of eggs. The daily feed intake of any given strain of hens cannot be accurately predicted, but depends not only on amino acid balance but also upon the energy content, palatability, environmental temperature, and other conditions. Consequently, it is impossible to say exactly how much improvement may be achieved by supplementing any given laying ration with methionine.

The Barrel Stave Analogy

All amino acids required for tissue synthesis must be present at the same time and in the proper amount at the site of the biological transformation into protein. A deficiency of any one essential amino acid means that the others remaining are wasted. Because of this, one can no longer consider

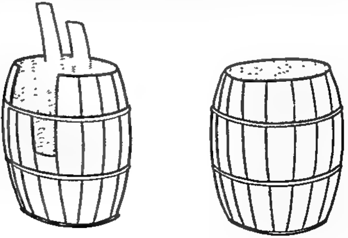


Fig. 17.2. Barrel Stave Analogy of Limiting Amino Acid Concept

An absence or deficiency of any one amino acid prohibits or limits protein synthesis.

simply the protein level of the diet in the determination of the nutritional adequacy. This is illustrated by the use of a barrel stave analogy. On the left there is a most unusual barrel with staves of irregular lengths. Some stick out above the rim; others are shorter than the rim of the barrel. It is readily apparent that the amount of water that can be held by the barrel is limited by the shortest stave, and that the rest of the staves serve no purpose. Suppose each barrel stave represented a particular amino acid and the rim or top of the barrel the amino acid requirements of the animal. Some proteins have less or more of a particular amino acid to satisfy requirements. Somewhat the same situation holds in the feeding of unbalanced proteins as with the water-holding capacity of the barrel. With all good analogies, there must be a moral and the moral of our barrel story, therefore, would be that the barrel is no larger than its smallest stave. The amount of protein that can be utilized by the animal for the tissue synthesis is determined by the first limiting amino acid with the remaining amino acids being lost to the animal. A complete deficiency of an essential amino acid would be represented by a missing stave and a barrel in which no water could be held. Such protein, if fed as the sole source of amino acid, is of no value to the animal because no protein synthesis can occur. The ideal barrel has all the staves of uniform length with no deficiency of staves. The ultimate in amino acid supplementation is when all amino acids present in the feedstuff are utilized with no surpluses for the animal to use up. An excess of amino acids in the diet is not only wasteful of the amino acids, but also of energy in that such energy could be more efficiently and economically obtained from fats or carbohydrates.

The NRC Amino Acid Requirements of Poultry

The amino acid requirements of poultry have been established by the National Research Council (NRC). These have been arrived at as the result of research from many laboratories on many types of diets. However, they are only rough approximations and hold true only for the diets containing protein of high biological availability and a relatively low energy level. The amino acid content of feedstuffs has been determined by chemical, microbiological, and chromatographic techniques. These values are available in tables from numerous sources. To determine if a particular diet is adequate for specific class of poultry, one must compute the amount of amino acids in the complete feed and compare these levels for the nutritional requirements of that animal.

The answer obtained by this method is only a first approximation, however, since many other factors must be taken into consideration: (1) biological availability of amino acids in each feedstuff; (2) plane of nutrition of the animal; (3) level of total protein in the diet; (4) the level of available energy in the diet; (5) the level of all other nutrients in the diet; (6) the level of non-

essential amino acids; (7) a ratio of certain essential amino acids to other essential amino acids; (8) the presence of unidentified factors; (9) the ratio of free to protein-bound amino acids; and (10) the age and strain of the animal. Thus, amino acid supplementation is not a simple problem of addition but requires careful evaluation of all of the above factors.

Even though many unanswered questions remain today, the knowledge obtained so far allows the nutritionist to formulate diets that are far superior in nutritional adequacy than formerly. Although it is difficult to believe in this present age of agricultural surpluses, trends indicate a serious shortage of high quality protein feedstuffs in the future. To obtain the most from the available sources of protein requires correct balancing of amino acid patterns. In many cases, this can be done only through the use of synthetic amino acids. When properly combined with natural protein, synthetic amino acids are capable of sparing the total need for protein. In some instances, as much as 200 lb of soybean meal can be spared by 2 lb of synthetic methionine. Soybean meal supplemented with methionine can be nutritionally comparable to fishmeal protein.

The season of the year greatly affects the results from methionine supplementation of laying feeds due to the fact that energy requirement of the hen inversely changes with temperature changes. During the summer months the birds cannot overconsume feed to the extent that they are able during the cool weather. Thus, the methionine level of the diet is more critical in the summer.

THE IMPORTANCE OF RATIONS HAVING BALANCED PROTEINS

Birds fed a balanced protein will not overconsume feed in order to meet their methionine requirements. The requirement of the laying hen is made up of two components—a maintenance requirement for the hen and a requirement for the production of the egg. It is important to keep the protein levels in practical rations moderate. They should not be reduced drastically without consideration as to the essential amino acid composition, nor should they be increased unduly in the hope that a little more of a good thing is even better.

With poults, methionine almost always improves the balance of amino acids so that improved weight and feed efficiency are obtained in the early periods of growth (Table 17.2). Lysine and arginine are the 2nd and 3rd limiting amino acids. Lysine supplementation, however, is most feasible in the finishing period, especially in the period beyond 16 weeks of age. As practical diets are decreased in protein, by substituting grains for soybean meal, lysine is reduced at a more rapid rate than protein. Therefore, lysine supplementation should be increased toward the end of the feeding period with the majority of the lysine being added in the last four weeks of the finishing period.

Fifty years ago, Osborne and Mendel first found that certain amino acids were dietary essentials. In contrast to the nutritionist's concern for essential amino acids, the nonessential amino acids are for the most part completely ignored in feed formulation. The amount of nitrogen furnished by them is not as important as the ratio of essential to nonessential nitrogen. As stated, from a nutritional standpoint, essential amino acids are those which cannot be synthesized at a rapid enough rate to permit the animal to obtain maximum performance for nitrogen retention and production of eggs. These will, of course, depend on the age, species, and reproductive state of the animal. A major factor in determining amino acid essentiality is the ability of the nutritionist to develop diets low in the amino acid of interest, but which will at the same time promote rapid enough growth that the animal's relative needs remain high.

TABLE 17.2

AMINO ACID STATUS FOR GROWTH OF CHICKS

Required	Required Under Certain Conditions	Should Be in Feed but Can Be Produced from Other Amino Acids
Methionine[1]	Cystine	Alanine
Phenylalanine[2]	Tyrosine	Aspartic acid
Glycine[3]		Hydroxyproline
Histidine		Proline
Isoleucine		Serine
Lysine[4]		
Arginine[4]		
Glutamic acid		
Threonine		
Tryptophan[4]		
Valine[4]		

[1]Methionine can replace all the cystine but cystine can replace only part of the methionine. Natural feeds, however, supply neither in sufficient amounts for both requirements.
[2]Phenylalanine can replace tyrosine but not vice versa.
[3]Glycine can be synthesized from acetates and replaced by creatine.
[4]Needs particular attention in practical feeds for chicks.

Amino acid antagonists or precursors further complicate the problem. As rations are formulated so as to have fewer and fewer excesses of essential amino acids, and as growth rate and reproductive performances increase, and as maximum feed efficiency becomes a criterion by which amino acids essentiality is defined, then some of the amino acids which have been traditionally labeled nonessential will become more important in feed formulation. Thus, good amino acid balance is an elusive will-of-the-wisp which every nutritionist tries to catch but which is difficult to measure. Even when it is obtained, a nutritionist is not sure he has it. Any excesses of amino acids lowers the efficiency of production since any surplus is eliminated and it takes energy to do this. It is possible through the use of modern elec-

tronic computers to formulate rations virtually void of excesses but such rations are not practical economically. It is, therefore, necessary to be aware of the effect of excesses of amino acids and the means of counteracting such excesses for the most effective and productive performances.

For efficient production, the daily ration must contain proper amounts of nutrients combined in the best possible manner—in other words in a balanced ration. If a ration is balanced in vitamins, minerals and energy, then how much protein is needed to complete the picture? There are few materials with such unusual diversity in its uses as methionine. It is necessary for growth, repair and metabolism of all tissues. Chemically, it is

$$CH_3{-}S{-}CH_2{-}CH_2{-}\underset{}{\overset{\displaystyle NH_2}{\overset{|}{C}H}}{-}COOH$$

Much of its versatility is attributed to the carbon-sulfur linkage and the labile methyl group. It converts dietary protein to tissue protein, maintains nitrogen balance, participates in sulfur metabolism, has transmethylation activity, is a precursor of bile acids, improves liver function, helps rebuild damaged kidney tissue, speeds wound healing, helps overcome adverse effects of stress factors such as temperature changes, disease,

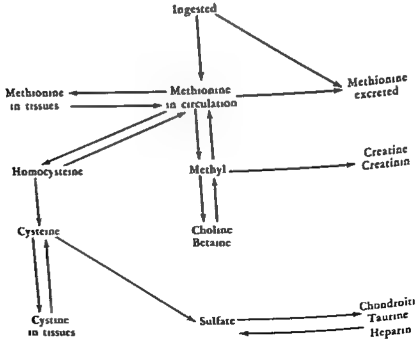


FIG. 17.3. METHIONINE METABOLISM

and over-medication, increases antibody production, acts as a detoxifier, and helps hormone activity.

Poultry require a certain amino acid be present in their diet, either as single acids or combined in proteins. These amino acids might be supplied by meat products, fish products, bacteria, protozoa or plant tissues. A balanced ration contains each nutrient in exactly the right amount so that no wastage or excess occurs in metabolism. Excess fats and carbohydrates in a ration can be stored in the animal's body as fat, but excess proteins cannot be stored for future use as proteins—they are deaminized and the nitrogen excreted as urea and ammonia and the remainder of the protein molecule used either for energy or storage as fat. Since the animal body does not have stores of protein which can be mobilized to supply proteins and amino acids in the event of a deficiency, it is necessary to supply nutrients continuously in optimum quantities at a proper time. So, the time of availability is important.

Certain amino acids are being synthesized commercially and are now available for feeding but it is more economical to supply them in the ration from natural feedstuffs. Poultry that eats and digests protein and builds up its own tissue protein might be compared to workmen tearing down a wall composed of blocks of about 20 different colors arranged in a definite design and then building another wall using the same blocks with a different design. There will be some blocks left over which are not needed in the new design and these are discarded. The animal burns the excess building blocks and gets energy out of them.

Anyone who has tried to combine protein supplements into a reasonable facsimile of the chicken's amino acid requirements has thought how nice it would be to have bins of amino acids at hand. One could then make the correct setting of the metering device and feed in the required levels of limiting amino acids to supplement the feed protein and arrive at exact levels required. Synthetic amino acids have been available for about a decade. Methionine was the first on hand, and more recently and less extensively synthetic glycine and lysine. Synthetic vitamins are widely used in feeds but it only takes a gram of riboflavin to fortify a ton of feed but it takes about a pound of methionine to do a similar job. Synthetic methionine first began to be used in quantity when the price came down to \$3.00 per lb, whereas riboflavin is considered economical at \$20.00 per lb. There are good economic reasons for trying to bring into the best possible balance the levels of energy, total protein, and essential amino acids. These account for more than 90% of the cost of poultry feed and it is in the energy and protein that the best opportunities lie for further improvements and economy of feeding. Results indicate that substantially less protein is needed for a given number of calories if the protein has been improved by amino acid

supplementation. It is likely that the generally accepted protein requirements of the different classes of poultry expressed as percentage could be lowered if the appropriate amino acid supplements are used. At $3.00 per lb, amino acids seem expensive. Perhaps the most important problem in feed formulation in the years ahead will be the determination of most economical combination of protein supplements, energy sources, and synthetic amino acids.

AMINO ACID CONTENTS OF THE PROTEINS OF GRAINS

Eighty-five percent of the cereal grains produced in the United States is consumed by animals. The two most important grains from a feeding standpoint are corn and grain sorghum. Corn is an established feeding grain; grain sorghums have increased in importance during the past 10 yr. Standard varieties of these grains have been largely replaced by higher producing hybrids with lower levels of protein. This has created considerable concern regarding the feeding value of these grains. From a nutrient standpoint, cereals must be evaluated on the basis of their ability to supply the requirements of the animal. While they are used primarily to supply energy, they also make important contributions of protein. The grains are not high in protein contents, they normally range from 8 to 13%. They do, however, contribute significant levels of protein in finished feeds, particularly where they make up 80% of the ration. The grains supply a third or more of the protein for birds having a protein requirement of 16–18%.

The major deficiency of most cereals when considered for poultry is the amino acid, lysine. They are not ideally balanced for supplying amino acids required by poultry. Therefore, supplementary protein sources and/or amino acids are needed to balance these rations adequately for animals. In the case of corn, both the amount of protein and the level of amino acids in the protein may vary due to an increasing proportion of zein with increases of seed protein. Different varieties of corn vary considerably in the amino acid composition of the protein—the largest differences being in arginine, histidine, lysine, leucine, threonine, and valine. Zein is low in lysine and thus higher levels of this protein result in a more unbalanced amino acid composition with relatively less lysine than the total protein. The average lysine value for No. 2 yellow corn is 0.18% with coefficient of variability of 37%. This indicates that the lysine value is between 0.11 and 0.25% approximately 68% of the time; above 0.25% approximately 16% of the time, and below 0.11% the other 16% of the time.

Imbalances are more serious with amino acid mixtures than with natural proteins because rapid absorption or even deaminization may occur before the amino acids reach the absorption site. Theoretically, every combination of protein will require slightly different amino acid needs. Fortunately, the

growing chick is versatile and can remake some of these amino acids into the ones that are needed most urgently.

Lysine Requirements of Chicks and Poults

A deficiency of lysine in the ration of turkey poults causes a lack of pigment or white bars to develop in the feathers. A lack of pigment in the feather follicle may be detected after ten days of feeding on a diet deficient in lysine and in two weeks the web emerges from the follicle to give the typical white bar pattern. It takes the same length of time to produce normal pigmentation upon supplementing the diet with lysine. This syndrome is interesting because it is one of the few instances in which a deficiency of an amino acid causes any symptom other than poor growth of the bird.

The requirements of chicks and poults for lysine are much higher than for methionine. Since the D form is inactive and the L form would need to be separated from the DL mixture produced by synthesis, twice as much would have to be used. This means that synthetic lysine would have to be available at a very reasonable price to be used in competition with the natural sources of protein.

STRUCTURE OF PROTEINS

(1) Keratins are found in hair, feathers, hooves, skin, and scales of fish. Cartilage, ligaments, and tendons are internal structures made of collagen and elastin.
(2) Muscle tissue are different type structures. Function: (a) storage of certain nutrients. (b) Enzymes: composed of amino acids (proteins) which control and regulate the biochemical reactions of the body; life depends on many interdependent reactions (heat, catalysts, pressure, and chemicals alter rate of reactions in test tubes).
(3) Hormones: many but not all are proteins. Insulin and oxytocin are examples of protein hormones. Hormones are metabolic regulators and generally do not control specific reactions.
   (a) May operate by stimulation or inhibition of enzyme systems.
   (b) May act directly on cell membrane. Insulin may function to get glucose into the cells; it may change arrangement of proteins in cell membrane and alter the permeability of the membrane to glucose. Also steroid hormones.
(4) Antibodies: consist of proteins and act to protect body from disease organisms.
(5) Toxins: are usually proteins.

SUPPLEMENTATION OF POULTRY FEEDS

In summary, the potential for amino acid supplementation of animal feeds is great. Many amino acid imbalances exist in nature. Since feeding

trials to test the quality of a protein concentrate are lengthy and costly in time and facilities, there is a need for chemical determinations that can be run in an ordinary laboratory which give results that can serve as an indicator of the quality of the protein in the sample. The nutritive value of a protein concentrate depends on (1) the amino acid composition; (2) the presence of trypsin inhibitors; (3) chemical changes produced during heating and storage since they interfere with the digestion of the protein and the complete utilization of those amino acids. The discrepancy of similar samples processed differently is due to having reduced the ability of digestive enzymes to release amino acids from the protein, although they could still be released by acid hydrolysis. A chemical reaction has taken place—a condensation between the aldehyde group of the sugar and the epsilon amino group of lysine. It is possible to measure the specific drop in lysine amino acid groups by reaction with fluoro-dinitrobenzene (FDNB) to give a dinitrophenol (DNP) compound. Acid hydrolysis of a protein tagged in this manner gives epsilon dinitrophenol lysine, a bright yellow compound which can be separated out by column chromatography.

In 1965, Purdue researchers found that corn seed contained a mutant gene for high lysine content. The new corn designated Opaque-2 contains approximately 69% more lysine than normal corn and it is also significantly higher in several other amino acids (arginine, glycine, cystine, isoleucine, and tryptophan) normally limiting in corn. The possibilities for greater dry matter yields of nutrients per acre from genetically improved corn will not be overlooked by a protein short world. In addition to corn, studies are continuing with other cereal grains as well as vegetable protein seeds to develop nutritionally improved species through mutation.

To recapitulate, in past years the percentage of crude protein in the feed has been used by poultrymen as an index of the quality of the ration. On the basis of present knowledge, a more critical and realistic measurement of the efficiency in laying rations is the balance of amino acids (the building blocks of protein) rather than the percentage of crude protein. Formulating rations on the basis of amino acid requirements is nutritionally sound and makes possible an effective ration with lower crude protein content. The use of improved techniques of formulation can result in producing eggs at a lower cost.

Supplementing Laying Rations

Improving the balance of amino acids in laying rations is one of the major factors that permits the economy of a lower protein level in the diet and yet maintains top laying hen performance. The most efficient use of feedstuffs for egg production, body maintenance, egg size, and a small amount of body growth is dependent on the ratios of amino acids to each other and to

the energy content of the ration. Since hens eat primarily to meet their daily energy needs, it is extremely important to have proper amino acid balance.

The wide variations in recommended levels of protein in laying rations which have led to much confusion among poultrymen are in large measure attempts to insure adequate intake of the amino acids needed to sustain high egg production. Formulating rations on the basis of total crude protein can result in some amino acids exceeding and some falling below the required levels.

A ration formulated to contain 19% crude protein could still have an inadequate balance of amino acids. Another ration formulated to contain 15% crude protein could have all the amino acids in the right balance to support maximum egg production.

AMINO ACID DEFICIENCIES OF FEED INGREDIENTS

Prior to 1900, poultry feeders were aware of the value of protein but they did not know why. The reason for this was that methods for the assay of protein or its constituents of amino acids had not been developed. Around 1900, methods for determining these basic amino acids began to be studied. In the 1920's, many methods were perfected and the differences in the quality of various proteins determined.

The by-products of animal origin are excellent sources of lysine, based on the animal's requirement for this amino acid. Milk products are outstanding sources of methionine, a sulfur amino acid. Bone meal is deficient in lysine, methionine, and tryptophan and this confirms the theory that the protein in bone is of a rather low nutritional value. The decided tryptophan deficiencies of meat scraps and meat products means that supplements of tryptophan would be required in order to balance the deficiencies of meat and bone products.

As to fermentation by-products, if the product came from a distillery making a bourbon whiskey, the mash will be very high in corn. Bourbon, by definition, has more than 50% corn, so the fermentation product would reflect the value of corn. In the case of rye whiskey, it would be rye grain. If the product was fermented for some other purpose, it always is necessary to go back to the constituents of the mash fermented. In general, they are deficient in lysine, as are the grains from which they were made.

Yeast has a high lysine content and it is sometimes used to balance grains in this amino acid. Some good sources of methionine are found among the fermentation feeds. In general, they are moderately deficient in tryptophan.

There are species differences in amino acid requirements. The rat is not as sensitive to amino acids as the chick. In the case of dispensable amino acids, this has significance only when the species and the age are stated. A

specific example of how these amino acids work together is the case of the two sulfur amino acids, cystine and methionine. Methionine can furnish part of the materials needed by the animals to synthesize cystine. Consequently, cystine is not necessary in the diet if there is sufficient methionine in the diet to meet the requirements of cystine. A similar situation holds for phenylalanine and tyrosine. Tyrosine is synthesized from phenylalanine but it is dispensable only when there is enough phenylalanine for both of the amino acids. Because of this sparing action, it is more economical and efficient to provide all of the amino acids in the diet. When protein is only slightly deficient, it is sometimes possible to meet the requirements of the animal by increasing the percentage of protein in the diet. If the animal is able to consume more, it is able to consume enough of the critical amino acid.

If more is fed, even though it is deficient, it will automatically take care of the deficiency to a certain extent. As an example, if a diet is short 10% in methionine, get the animal to consume 10% more of the diet and the methionine requirement is met. A third method which can be used is to use a combination of proteins so that the shortcomings of one protein will be offset by the abundance of certain amino acids in other proteins.

Excess amino acids are excreted. At first, they are used for energy or changed to carbohydrate. There are 3 or 4 different kinds of methionine and methionine analogues that can be purchased. It is better to add it as the amino acid or as fishmeal. It is a matter of economics.

In nature, the amino acids are in the chain form but when the chemists can make them, they are most likely in the D-form or the combination DL form. Also, they can be obtained as the hydroxy analogue. Are they all equal in value? In general there are no demonstrable differences in the potency of the methionine isomers. Under conditions of large metabolic loads of D-isomers, there is evidence that methionine is usually less effective than the DL which is the natural type. Most nutritionists use methionine on the basis of equivalents with respect to methionine content because they do not have the same amount of methionine in their product. For example, the methionine hydroxy analogue calcium has the value of 80.1% of the DL-methionine which is 99% pure. In other words, this would be 1¼ lb of the analogue used for every 1 lb of DL-methionine. The only other amino acid which is used as the amino acid is lysine because others are difficult to produce. Lysine is expensive so that it cannot be used in commercial rations but for research work it is often used. But for the practical feeding of birds, feedstuffs which contain lysine in natural form are used in fairly large amounts.

Biological values of protein are a measure of protein retention by the bird. It relates particularly to the pattern of amino acids in that particular

protein. That is why mixtures of proteins are used to meet the protein requirements of an animal. By blending these, they help balance out deficiencies. The biological values of protein are useful but they do not disclose the exact nature of differences in feeding values.

Equal amounts of blood meal and corn gluten meal would just about meet the nutritive requirements of broilers. Soybean meal is short on methionine but it has plenty of lysine. Sesame meal is long in methionine but short on lysine. Combining them meets the requirements for the two amino acids. Sesame meal, however, is different from most vegetable meals because it is higher in methionine.

Feed laws require that the protein percentages be put on the feed tag. But you can have a good protein analysis and still the feed might not be worth much. For example, if you ground up leather and put it in the ration, you would get a high protein content but the protein is keratin, a type of protein not digestible or utilized by the animal. The protein has to be digestible by the animal.

Furthermore, if products have been subjected to overheating in pro-

TABLE 17.3

FACTORS FOR CALCULATING PROTEIN FROM NITROGEN CONTENT OF FEED

Feed	Factor	Feed	Factor
Animal origin			
Eggs	6.25	Peanuts	5.46
Gelatin	5.55		
Meat	6.25	Seeds	
Milk	6.38	Cottonseed	5.30
		Flaxseed	5.30
Plant origin		Hempseed	5.30
Barley	5.83	Sesame	5.30
Maize (corn)	6.25	Sunflower	5.30
Millet	5.83		
Oats	5.83		
Rice	5.95		
Rye	5.83		
Sorghums	6.25		
Wheat			
Whole kernel	5.83		
Bran	6.31		
Embryo	5.80		
Endosperm	5.70		
Legumes			
Beans			
Lima	6.25		
Mung	6.25		
Navy	6.25		
Soybeans	5.71		
Velvetbeans	6.25		

cessing, the protein content may have been damaged. Proteins and amino acids combine with carbohydrates in the presence of heat and produce undigestible material. This is called the "browning reaction" and must be taken into consideration in all calculations. In other words, it is important to know the particular lots of products that are to be used. For that reason, feed men usually make their purchases from companies they are familiar with. For instance, they might specify that fermentation products come from a plant that is producing bourbon whiskey whose mash will be high in corn and whose operation is continuous.

There are several ways of drying fish. Flame-drying fish where it is exposed to a blast of air from burning oil might bring the meal up to a very high temperature if there was some difficulty in operation. If the meal is blown into a big pile, containing thousands of tons, it does not cool very fast. It may be days or weeks before it gets down to a low temperature and the chances are that the meal would not be as good as meal dried by steam at a lower temperature or meal dried more rapidly by flame drying. Fishmeal dryers usually cool the meal to prevent heat damage.

DETERMINING THE PROPORTION OF CORN TO PROTEIN SUPPLEMENT FOR USE IN RATIONS

A simple method of determining how much grain and how much protein supplement to use to make a mixture with a certain protein content follows. In this example, a mixture containing 16% protein is to be made from corn containing approximately 9% protein and supplement containing 40% protein.

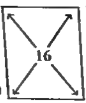
Draw a square. In the center of the square, put the proper content desired in the final mixture. At the upper left-hand corner of the square, write "corn" and its protein content (9); at the lower lefthand corner, write "supplement" and its protein content (40).

Subtract diagonally across the square (the smaller from the larger), and enter the results at the corners on the right-hand side (16–9 = 7;40–16 = 24).

The number at the upper right-hand corner gives the parts of corn and the number at the lower right-hand corner, the parts of supplement needed to make a mixture with 16% protein.

Corn 9

24 parts corn or 77%
(24 ÷ 31 = 0.77 × 100 = 77%)



Suppl. 40

7 parts supplement or 23%
(7 ÷ 31 = 0.23 × 100 = 23%)

31 parts

Therefore, a mixture of 77 lb of corn and 23 lb of protein supplement would make a ration containing 16% protein.

Calculating the protein content of a ration:

Lb	Ingredient		% Protein in feed		
1500	ground corn	×	0.09		135.00
150	soybean meal	×	0.44	=	66.00
100	meat and bone meal	×	0.50	=	50.00
200	alfalfa meal	×	0.17	=	34.00
6	dicalcium phosphate				
10	salt				
10	vitamin-trace mineral premix				
2000					285.00

285 ÷ 2000 = 0.143 × 100 = 14.3% prot.

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Fats

PART 1 Introduction and Chemistry

Fat is important in feedstuffs because: (1) the rate of growth is often improved, and (2) of more importance, fat increases feed efficiency and thus less feed is required per pound of gain. Fats are glyceryl esters of certain acids (chiefly oleic, palmitic and stearic acids) in animal fats as shown in Tables 18.1 and 18.2. Tests have shown that color per se has no effect on feeding performance. High free fatty acid (FFA) levels in certain feeds have always been considered undesirable because FFA develops from bacterial and enzymatic action, often the reflection of careless handling prior to rendering. Also, oxidation leads to rancidity and produces FFA as a by-product, therefore, high FFA levels have been associated with poor quality fats. However, this conception has been altered with the introduction of hydrolyzed fat which contains high levels of FFA produced intentionally by separating fatty acids from glycerol. Antioxidants are added immediately to stabilize the free fatty acids and thus the undesirable side reactions which produce FFA in carelessly handled natural fats are avoided. Fats containing high levels of FFA are for all practical purposes equal in feeding values to fats containing low levels. FFA per se are a good source of energy.

In the latter part of 1957, a condition known as hydropericardium "water belly" or edema killed many broilers. Autopsy of the affected birds showed an exceptional amount of a clear, straw-colored fluid in the pericardial sac and a general edematous condition so severe that often the whole peritoneal cavity was filled with fluid. Degenerative changes in the liver and heart muscle were frequently found. The liver was tan in color and had a mottled appearance. This syndrome was caused by isolated shipments of feed grade fat which were used in broiler feeds. The fat sold as no. 2 tallow contained a toxic fraction not ordinarily found in fats.

This product should not have been sold for use in feeds and tentative definitions and standards adopted by AAFCO serve as a guide to prevent use of such products in the future. The toxic material was found in the black, tarry residue, the low purified fractions of the fat, and total fatty acids (TFA). Whole fat is composed of approximately 90% fatty acids and 10% glycerol. Thus, fatty acids supply more than 90% of the energy of whole fat. Glycerol contains only 4.32 Cal per gm while whole fat contains

TABLE 18.1

COMPOSITION AND CONSTANTS OF FATS AND OILS

Fatty Acid	Chemical Formula	Double Bonds	Corn	Cotton-seed	Lin-seed	Olive	Peanut	Rape-seed	Saf-flower	Sesame	Soy-bean	Lard	Tal-low	Her-ring	Menha-den
Saturated															
Caproic	$C_6H_{12}O_2$	0	...	...	...	...	...	...	...	...	...	...	...	...	...
Caprylic	$C_8H_{16}O_2$	0	...	...	...	...	...	...	...	...	...	...	...	...	...
Capric	$C_{10}H_{20}O_2$	0	...	...	...	...	...	...	...	...	...	...	...	...	...
Lauric	$C_{12}H_{24}O_2$	0	...	...	...	...	...	...	...	...	...	...	0.1	...	0.1
Myristic	$C_{14}H_{28}O_2$	0		0.5		0.5		0.5	0.1		0.1	1	3	7	7
Palmitic	$C_{16}H_{32}O_2$	0	8	21	5.5	9.5	7	2	4.5	8	8	28	29	14	16
Stearic	$C_{18}H_{36}O_2$	0	3.5	2	4	2.0	4	0.9	2	4	4	13	20	0.5	2
Arachidic	$C_{20}H_{40}O_2$	0	0.5	0.2	0.3		3	0.5	0.4	0.5	0.6		0.8		
Behenic	$C_{22}H_{44}O_2$	0					2	1		0.1					
Lignoceric	$C_{24}H_{48}O_2$	0	0.2	0.3	0.2		2	1		0.1					
Unsaturated															
Myristoleic	$C_{14}H_{26}O_2$	1	...	...	...	...	...				0.1	0.2	0.5	0.5	0.1
Palmitic	$C_{16}H_{30}O_2$	1	...	...	...	...	...	0.1			0.2	3	2	6	16
Oleic	$C_{18}H_{34}O_2$	1	46	29	22	81	60	18	20	45	28	46	42	21	15
Erucic	$C_{22}H_{42}O_2$	1	...	...	...	...	...	51							
Linoleic	$C_{18}H_{32}O_2$	2	42	45	17	7	22	22	70	42	54	6	2		7
Linolenic	$C_{18}H_{30}O_2$	2	...	2	51	...	...	3	3		5	0.7	0.5		3
Arachidonic	$C_{20}H_{32}O_2$	3	...	...	...	...	...					2	0.1	28	17
Clupanodonic	$C_{22}H_{34}O_2$	4	...	...	...	...	...							23	11
	$C_{24}H_{38}O_2$	5	...	...	...	...	...								4
	C_{26}		...	...	...	...	...								1
	Over C_{26}		...	...	...	...	...								2

TABLE 18.2

FATTY ACIDS OF FEED FATS

Acetic Series ($C_nH_{2n}O_2$)
- Lignoceric, $C_{24}H_{48}O_2$—rape, peanut, soy, sesame, sunflower, maize
- Behenic, $C_{22}H_{44}O_2$—rape and other cruciferous seeds
- Arachidic, $C_{20}H_{40}O_2$—peanut, soy, cottonseed, olive, sesame, sunflower, maize
- Stearic, $C_{18}H_{36}O_2$—Solid fats and most oils
- Palmitic, $C_{16}H_{32}O_2$—most fats and many oils
- Myristic, $C_{14}H_{28}O_2$—palm kernel, coconut, walnut, rape, cottonseed, olive
- Lauric, $C_{12}H_{24}O_2$—pine nut, palm kernel, coconut
- Capric, $C_{10}H_{20}O_2$; Caprylic, $C_8H_{16}O_2$; Caproic, $C_6H_{12}O_2$—butter, palm kernel, coconut
- Butyric, $C_4H_8O_2$—butter

Oleic series ($C_nH_{2n-2}O_2$)
- Erucic, $C_{22}H_{42}O_2$—rape, cod liver oil
- Oleic, $C_{18}H_{34}O_2$—oils and most fats

Linoleic series ($C_nH_{2n-4}O_2$)
- Linoleic, $C_{18}H_{32}O_2$—hemp, poppy, rape, almond, peanut, soy, linseed, cottonseed, olive, sesame, sunflower, maize

Linolenic series ($C_nH_{2n-6}O_2$)
- Linolenic, $C_{18}H_{30}O_2$—beechnut, hemp, poppy, rape, soy, linseed
- *Isolinolenic—hemp, linseed, madia*

Clupanodonic series ($C_nH_{2n-8}O_2$)
- Clupanodonic, $C_{18}H_{28}O_2$—marine oils

around 9.2 Cal per gm. Therefore, TFA is an index to the energy value of the fat. Definitions call for a minimum of 90% TFA in animal and vegetable fats and 85% in hydrolyzed fats and esters. Kerosene insolubles are present at very low levels in fat. These are usually very minute particles of fiber, hair, hide, bone, minerals, and metal. They are not harmful nutritionally but too many insolubles plug up fat handling equipment, such as screens and nozzles. Definitions call for not more than 1% insoluble matter.

Unsaponifiable Matter

Unsaponifiable matter is not harmful to chicks. Hydrolyzed fats containing relatively high levels of unsaponifiables are good sources of energy. Definitions limit the amount of unsaponifiable matter to a low practical level—in animal fat, 2¼%; in vegetable oils, 2%, and in hydrolyzed fats and esters 6%. If an antioxidant is used as a stabilizer in fats, the common name or names should be indicated, followed by the word "preservative." All fats used in feeds should be stabilized. In addition to the above, moisture content should be kept at a minimum. Three percent or more moisture causes corrosion of metal in fat handling equipment. Care should be taken in the feed mill to keep fat dry and prevent moisture pickup.

MIXING FATS WITH OTHER FEEDSTUFFS

Mills located close to the source of fat supply receive shipments in tank trucks since the heat loss is usually low enough so that heating is unnecessary for unloading. The unloading of tank cars presents more of a problem since the time involved usually solidifies the fat during shipment and thus it is necessary to heat the cars to unload. The size and location of the heating coils vary, but normally they consist of about eight, 35-ft lengths of ½ to 2-in. pipe. Most cars have a connection at the end or the bottom of the car. In heating the cars, 100 to 150 lb of steam are used and the fat is heated to 175° F. Care is taken not to overheat since expansion of the fat may cause full cars to overflow. Heating is continued until the bottom of the car is hot along its full length and there is no bridging of the fat in the upper portion of the car. This takes 4.5 hr after which 75% of the car can be unloaded. The remainder is then heated until the ends of the car are too hot to touch, then the fat is pumped out. The overall time usually is 7 hr for cars having connections at the ends or bottom. Sometimes unloading times can be shortened by recirculating the fat—pumping the hot fat from the bottom back into the top. A channel is formed in the unmelted fat and increased circulation and agitation speed up the melting process.

Fat stored should be at as low a temperature as possible while keeping it fluid enough to handle. Where fat is used daily, a storage temperature of approximately 120° F is sufficient Provisions are made in storage tanks to allow periodic bleeding off of water which may separate to the bottom of the tank. Storage tanks are cleaned out every three months. During shutdowns and over weekends lines should be blown out and drained free from fat. To prevent fat from solidifying, lines should be steam traced by wrapping copper tubing around them. The mixing of fat in feeds is accomplished in any type of feed mixer—horizontal, vertical, and continuous mixers. Where the batch-type mixer is used, measured amounts of fat can be run into the feed while the mixer is running. A simple method commonly used, is a bucket with holes punched in the bottom so the fat is introduced slowly into the feed. With large mixers, the fat can be added directly in a small spray at a point where there is sufficient agitation of fat and feed before cooling takes place. In continuous mixers, fat is added along with the other ingredients but admitted at a point where most of the other ingredients have already been in contact with the mixing screw. In order to avoid fat balls in the feed, steam the fats before adding to the feed. A heat exchanger is provided with thermostatic controls to maintain a constant temperature. The required temperature varies from mill to mill and season to season but usually will range between 140° and 200° F.

Where fat is received in drums, immersion type heaters, wrap around heating belts, and metal case units can be used to melt the fats. All are

portable and fairly simple to operate. The desirability of retaining pellet hardness and durability has led to the introduction of fats to pellets after they are formed. A simple, low-cost operation involves spraying hot fat onto the controlled and measured stream of cooled screened pellets which then pass into a retention drum until the fat cools and hardens on the pellet. The pellets are then either binned or sacked.

Fat should be stabilized when used for its energy content in poultry feeds. Fats aid in pelleting and are a source of essential fatty acids. Chickens can tolerate high levels of fat, but economics usually indicate levels of 2 to 4%. Animal tallow and grease, acidulated soap stocks, and vegetable oil foods are all used in chick feeds and should be low in moisture, and free from suspended solids. Fat products should be checked to be certain that they are not toxic.

Advantages of Fats in Feeds

Calories added in the form of rendered animal fat are well utilized by poultry for meat or egg production. Fat contains 2¼ times as many calories per pound as protein or carbohydrate. On this basis, the increased caloric content per unit weight of feed obtainable through addition of fat is of particular advantage in the formulation of high energy diets. No feed ration is better than its limiting factor. Protein, minerals, and vitamins must, therefore, be sufficiently high to permit dilution by the added fat. Fat is usually added at levels of 3 to 6% by weight of the complete feed formula. This provides a total of from 6 to 11% of fat in the feed and these levels have proved quite satisfactory. From the palatability standpoint, the addition of animal fats to feeds appears to have offered an effective answer to the common problem of dustiness of feeds which affects palatability. It may have more influence on growth results than is currently recognized. The stability of vitamin A is greater in the presence of stabilized animal fats. The use of antioxidants in fats for feeds not only does not impair, but actually contributes to maintenance of vitamin stability. Many grades of tallow or grease can be utilized just as satisfactorily as choice white grease, providing safeguards have been taken against rancidity and if the fat has no objectionable odor.

Animal Fats and Oils

(American Feed Control Official Association).—Animal fat is the product obtained from the tissues of mammals and/or poultry in the commercial processes of rendering or extracting. It consists predominately of glyceride esters of fatty acids and contains no additions of free fatty acids or other materials obtained from fats. It shall contain not less than 90% total fatty acids, not more than 2.5% unsaponifiable matter, and not more than 1% insoluble matter. If the product bears a name descriptive of its

type or origin, for example, "tallow," "lard," "grease," it must correspond thereto (Table 18.3). If an antioxidant is used, the common name or names shall be indicated followed by the word "preservative" or "preservatives."

Definition of Vegetable Fat or Oil.—Vegetable fat (or oil) is the product of vegetable origin obtained by extracting the oil from seeds or fruits which are commonly processed for edible purposes. It consists predominantly of glyceride esters of fatty acids and contains no additions of free fatty acids or other materials obtained from fats. It shall contain not less than 90% total fatty acids, not more than 2% unsaponifiable matter, and not more than 1% insoluble matter. If the product bears a name descriptive of its kind or origin, for example, "soybean oil," "cottonseed oil" it must correspond thereto. If an antioxidant (or antioxidants) are used, the common name or names shall be indicated, followed by the word "preservative" or "preservatives."

Hydrolyzed Fat or Oil.—Hydrolyzed fat or oil (feed grade) is a product obtained in the fat processing procedures commonly used in edible fat processing or soap making. It consists predominately of fatty acids and shall contain not less than 85% total fatty acids, not more than 6% unsaponifiable matter, and not more than 1% insoluble matter. Its source shall be stated in the product name, for example, "hydrolyzed animal fat," "hydrolyzed vegetable oil," "hydrolyzed animal and vegetable fat." If an antioxidant (or antioxidants) are used, the common name or names shall be indicated followed by the word "preservative" or "preservatives."

"Fat Product."—Fat Product (Feed Grade[1]) is any fat product which does not meet the definitions for animal fat, vegetable fat or oil, or hydrolyzed fat or fat ester. It shall be sold on its individual specifications. If an antioxidant (or antioxidants) are used, the common name or names shall be indicated, followed by the word "preservative" or "preservatives."

Fatty acids are divided into saturated and unsaturated. Unsaturated ones have from 1 to 5 double bonds; safflower oil has many double bonds compared with the others. There are differences in the composition of these fats and oils.

Grade Selection, Stabilization and Use of Animal Fats in Feeds

Animal fats commercially available for use in feeds are rendered from animal tissues accumulated during conversion of livestock to meat. Ren-

[1]The use of the term "feed grade" requires that the specific type of product will have been adequately tested to prove its safety for feeding purposes. In mixed feeds containing fats or fat derivatives "feed grade" defined above, the term "feed grade" may be omitted in the ingredient declaration.

Any mixture of two or more fats or fat derivatives defined above is to be identified by listing each component, for example, "animal fat and hydrolyzed vegetable oil."

dered greases and tallows are termed "inedible" although they are processed at sterilizing temperature.

Inedible animal fats are segregated according to titer (melting point) into two classes. Those with a titer of 104° F or higher are tallows; those with a titer of less than 104° F are greases. Each class is further divided into grades based on free fatty acid (FFA) content and color maximum. Characteristics of the commonly recognized grades of animal fats are outlined in the table following.

TABLE 18.3

CHARACTERISTICS OF INEDIBLE GRADES OF ANIMAL FATS

Fats	Titer (Minimum)	F.F.A. (Maximum)	M.I.U. (Basis)	F.A.C. Color Maximum Untreated and Unbleached
Tallows				
Fancy	41.5	4	1	7
Choice	41	5	1	9
Prime	40.5	6	1	13 or 11B
Special	40.5	10	1	19 or 11C
No. 1	40.5	15	2	33
No. 2	40.5	20	2	37
No. 3	40	35	2	No color
Greases				
Choice white	37	4	1	11
A, white	37	8	1	15
B, white	36	10	2	19 or 11C
Yellow	36	15	2	37
House	37.5	20	2	39
Brown	38	50	2	No color

Grade standards established as a measure of quality are not of major significance as far as suitability for use in feeds. It would be wise to avoid fats with excessively high FFA, but color values and M.I.U. possess no particular meaning as applied to the use of fats in feeds.

There are no nutritional reasons why most grades would not be equally satisfactory in feeds. Palatability and stability are the major considerations in feeds and are not specified in quality grades. The nature and condition of the raw materials rendered have an important bearing on the quality, including palatability and stability. Consequently, some feed manufacturers specify No. 1 tallow or yellow grease, although further work may show that lower grades can be used.

The factor of stability of fats deserves special mention. If a fat is not stable and becomes rancid, it becomes unpalatable to animals and feed consumption is reduced. Fat rancidity also lowers nutritional value be-

cause it promotes destruction of vitamins A, D, E, and some of the B-complex.

To avoid this a suitable antioxidant is used to stabilize fats for feeds. One antioxidant usually used for this purpose is butylated hydroxyanisole (BHA). It has been approved by the Federal Food and Drug Administration for use in feeds and has a superior antioxidant activity. Incorporation of antioxidant in fat is simple, since it is soluble in fat, the only precautions needed are that the fat must be warm and liquid and that some method of agitation must be provided. Good results are obtained with a 15-min stirring period at 130° F.

The amount of fat going into the feed is measured by various means:—from weighing in a bucket to very elaborate equipment for automatic proportioning. Flow meters or proportioning pumps are used, either manually or automatically controlled. The simplest manually operated flow meter will be found useful since it can be set for any percentage level of fat to be added and will maintain this percentage regardless of other variations in mixer operations.

CHEMISTRY OF FATS AND OILS

In the summer, greases can be pumped; in winter with lower temperatures a more flowable hydrolyzed animal and vegetable fat product may be used. If fats or greases are heated they will usually stay hot enough to run into the feed so that they cover the surface of the particles and mix very well. Hot fats hold heat a long time so they can be transported by truck for long distances. Trucks that roll from Chicago with tallow are still liquid when they arrive in Detroit and can be pumped without extra work.

Neutral fats are triglycerides of fatty acids and glycerols. Interest in them derives primarily for energy, essential fatty acids, and certain fat-soluble vitamins for which they are carriers. Fats differ from oils in that they are solid at room temperature. The fat industry following trade practices of the soap industry describes them according to certain characteristics of their inedible grades. They are classified as follows: fancy, choice, prime and then numbers 1, 2, 3; for greases, choice white, A-white, B-white, yellow and brown. Choice white grease is the top grade. Greases and tallows are distinguished by melting temperature which is called "titer." The minimum titer of oils, such as corn oil, produces a fat which flows and can be pumped even in winter without heat. Some commercial fats contain fatty acid residues from the production of glycerol for anti-freeze. Fatty acids are usable as fat because they contain carbon, hydrogen, and oxygen, but they differ among themselves in nutritional value. Those

with a higher titer are less valuable than those with lower ones. . . . Bleached and unbleached fats are available.

Fats are sometimes hydrogenated or saturated to produce a dry, free-flowing product with a titer of 131°F, free fatty acid 10%, and iodine value of 15. Saturation eliminates the danger of further oxidation, the precursor of rancidity. Saturated fats will not "bleed" into cloth or paper containers which can be a problem.

Either animal or vegetable fat is wholesome and nutritious at high as well as low levels in the diet. At the University of Maryland, a ration containing 30% animal fat was fed with excellent results. All the carbohydrate portion of the diet was replaced with corn oil. In this work, birds averaged 3.04 lb in weight at 7 weeks of age and required only 1.04 lb of feed per pound of gain. Fat is the most concentrated source of food energy presently known.

Fat is sometimes added to pellets after they are formed. A simple low-cost operation involves spraying hot fat on to a controlled measured stream of cooled pellets which then pass into a retention drum until the fat cools and hardens on the pellets. The pellets are then either binned or sacked.

Lecithin in Fats

Accompanying animal and vegetable fats is lecithin, a fatty substance containing nitrogen and phosphorus. Lecithin denotes a group of fatty substances, phosphatids, which occur throughout nature as an essential part of living organisms. Lecithin is easily absorbed, and functions in part as an emulsifying agent to promote better absorption of fatty materials and other food elements. It is an excellent emulsifying agent which improves food utilization and enters into the structure of living cells.

TABLE 18.4

EFFECT OF FFA LEVEL AND FAT SOURCE ON FAT PERFORMANCE (8-WEEK RESULTS)

Fat Level	% FFA	Weight Lb	Feed per Pound of Gain (Lb)
No added fat	. . .	2.99	2.28
15% animal fat	7	3.10	1.94
15% animal and vegetable fat (primarily animal)	39	3.15	1.94
15% animal and vegetable fat (primarily animal)	79	3.15	2.08
15% vegetable fat	81	3.05	2.04

Lecithin contains choline which prevents perosis in poultry. In the form of lecithin, choline is particularly effective. One of the substances contained in the commercial product is an inositol compound which functions in the growth of feathers. Inositol has a bearing on the transport of fats

from the liver to other parts of the body. Commercial soybean lecithin contains ethanolamine and small amounts of biotin and tocopherol (vitamin E). Lecithin has protective action against eczemas of nutritional origin and helps maintain the animal in the state of good health.

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PART 2 Pigmentation

CONSUMER PREFERENCES

Wholesale buyers of poultry of the United States offer a premium for deeply colored broilers and roasters. Housewives like eggs that range in color from pale to deep yellow and object if yolks are orange-red. On the other hand, deep orange yolks are desired for commercial use in egg noodles, yellow cake mixes, and other products made for food processing.

Consumers' strong preference for highly pigmented broilers is associated with freshness and wholesomeness. The "golden glow" of the broiler sells more of them and brings better prices. Consumers in the United States, Mexico, Germany, and Italy desire a deep yellow skin in the dressed carcass while in England and France the skin must be white.

In 1922, Palmer proved that it was the xanthophylls of the diet that produce yellow pigmentation of the skin and fat of chickens, and carotenes play no important part in this. All English breeds have white skin, except the Cornish. These include the Dorking, Australorp, Sussex, and Orpington. Thus, there are breed differences with respect to pigmentation. Growing pullets of yellow-skinned breeds store pigment steadily in the fatty tissues of the body. At the start of egg production, all pigment absorbed from the diet is diverted to the ovary and leaves the body as a component of the egg yolk. The laying pullet loses her tissue pigmentation in a definite pattern, skin first and shanks last. Regardless of the concentration of the xanthophylls in the feed, when egg production ceases, pigmentation returns again to the various parts in the same order as it disappeared at the start of production.

Anything that interferes with the egg-feed ratio affects yolk color. The hen that lays an egg every other day puts more pigment in her yolk than the hen that lays an egg every day, even though they consume the same diet. Hot weather reduces the efficiency of xanthophyll utilization. "Platinum yolk" and "lemon yolk" eggs occur occasionally. There is some question whether the condition can be transmitted from one group of birds to another. It can be corrected by feeding an antibiotic or furazolidone, so it is attributed to a low-grade infection or capillaria worms. *Eimeria maxima* is highly detrimental to skin pigmentation. Less difficulty with yolk pigmentation is experienced with layers in cages, which lends support to the idea that coccidiosis may sometimes be involved.

CAROTENOID PIGMENTS

Most yellow and red pigments synthesized in vegetable materials are a closely related group of chemical compounds known as carotenoids. Peppers and paprika contain capxanthin as well as xanthophyll and are effec-

tive pigmenters. Some substances introduce abnormal colors which are not acceptable to consumers. For example, bixin and capxanthin produce red yolks; canthaxanthin produces orange-colored yolks. Annatto (achiote) contains bixin and xanthophyll. Under normal feeding practices 70% of the yellow color of egg yolk is due to xanthophyll, and most of the remainder is due to zeaxanthin.

Broiler pigmentation is measured by visual comparison or extracting the yellow pigment from a sample taken from the toe web. A number of arbitrary scales are used for grading pigmentation. Results are expressed in terms of color equivalent to a specified carotene content in ppm of the sample. The eye detects colors which are not measured by a photoelectric colorimeter.

Most color in the shanks, skin, and body fat of poultry is a single pigment, xanthophyll (lutein), although other hydroxycarotenoids are deposited. No nutritional function has been demonstrated for xanthophylls and their deposition in egg yolks is mainly a convenient means of disposal. Nonvitamin A carotenoids are known collectively as xanthophylls and possess structures which birds are unable to convert into vitamin A. They are absorbed from the intestinal tract and deposited in fatty tissues and egg yolks as intact chemical compounds. Some are poorly absorbed or have different degrees of absorption. Absorption of carotenoids follows closely that of lipids. Vitamin E protects pigmentation.

Carotene is a yellow pigment, crystallized from carrots by Wachenroder in 1826 and is a precursor of vitamin A. In 1837, Berzelius extracted from autumn leaves a yellow pigment known as xanthophyll. In 1906, Tswett extracted pigments of nettle leaves and passed the solution through a tube of calcium carbonate. A series of yellow layers formed which he separated and showed to contain different xanthophylls.

Xanthophylls

Xanthophylls (plural) refer to the entire group of hydroxycarotenoids; whereas, xanthophyll (singular) refers to lutein. As a class of compounds they have no nutritional value. Green, leafy materials are excellent sources of xanthophyll Alfalfa has 5 major xanthophylls which constitute 99% of the total xanthophylls present: lutein, cryptoxanthin, zeoxanthin, violaxanthin, and neoxanthin. "Dehy" is the most desirable with regard to xanthophyll content. Two and one-half percent of 20% protein dehy is equal to 5% of the 17% protein grade. Pelleting and regrinding alfalfa leaves causes an increase in pigmentation. Alfalfa carotenoids and xanthophylls are absorbed as well as those of corn or corn gluten meal.

Sources of Xanthophylls.—Practical sources of xanthophylls are yellow corn and corn gluten meal. Yellow corn varies in xanthophyll content and

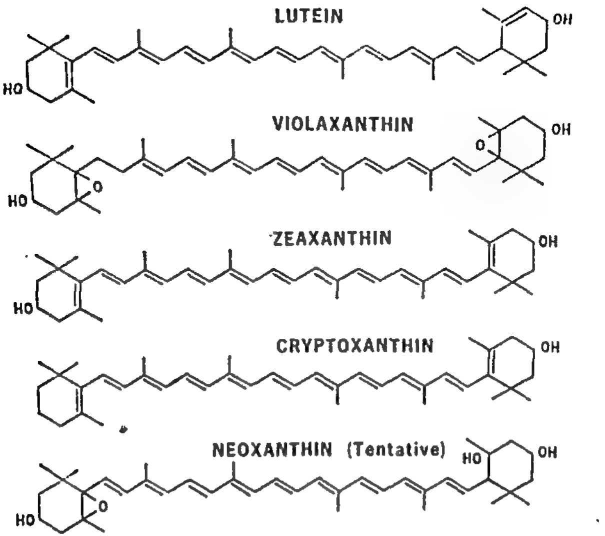

Fig. 18.1. Structures of Five Main Xanthophylls of Alfalfa

cannot be depended upon to take care of xanthophyll requirements by itself. The supply of corn gluten meal is limited by the amount of corn milled and is frequently in short supply. Yellow corn contains chiefly lutein, zeoxanthin, zeinoxanthin, and tryptoxanthin. Thus, the substances responsible for broiler pigmentation are part of a complex of related chemical compounds or their degradation products. The pigmentation of corn gluten meals varies according to the xanthophyll content of the corn used in its manufacture and is principally a seasonal variation. Periodic xanthophyll analyses insure uniform pigmentation at minimum cost.

A synthetic carotenoid beta-apo-8′-carotenal is well utilized for pigmentation. Violaxanthin is ineffective as a yolk pigmenter whereas zeoxanthin and beta-apo-8′-carotenol produce a pleasing golden glow. Canthaxanthin and isozeoxanthin are readily utilized by the hen, but yolk color has an undesirable orange tinge. Arsenicals and antibiotics have been noted by some to enhance pigmentation. From a practical standpoint of pigment, it is the eye of the viewer that really counts.

Stability of Xanthophylls.—Xanthophylls are not stable compounds and can be lost from poultry feeds by oxidation. The amount of yellow pigment deposited in the skin of broilers is significantly increased when an antioxidant is added to the feed and destruction in the feed is reduced appreciably. This is effective in preserving the xanthophyll in corn as well as dehydrated alfalfa meal. Minerals and other ingredients have prooxidant effects. Fat improves absorption of xanthophyll but it has an adverse effect if it induces oxidative rancidity. Oxidation can occur on storage, in the intestine, or after absorption. To protect against oxidation, antioxidants are incorporated in poultry pigmenters.

Charcoal, mineral oil, and sulfur in the diet interfere with deposition of xanthophylls in chicken tissue, as does cod-liver oil and sardine oil at high levels. Pigment suppression occurs with certain meat scraps, fishmeal, and soybean meal samples. Some kinds of respiratory diseases and chronic intestinal parasite infestations have been implicated in pigment suppression.

Newly recognized sources of xanthophylls are algae meal and flower petal meal (Florafil). These are of interest because of the high concentration of xanthophyll. Florafil is a natural plant product. Petals from the blooms of a specially selected species of marigold grown in Mexico are a

TABLE 18.5

THE AVERAGE XANTHOPHYLL CONTENT OF FEED INGREDIENTS

Ingredient	Mg Xanthophyll per Lb
Flower petal meal (Florafil)	4500
Dried algae meal	1000
Dried stinging nettles	370
Broccoli leaf meal	303
Dried koa haole meal	300
Dehydrated clover meal	223
African red peppers, powdered	200
Dehydrated alfalfa leaf meal (20% prot.)	180
Dehydrated alfalfa leaf meal (17% prot.)	85
Spanish paprika	125
Ground annatto seed and hulls	120
Dried chili peppers	85
Corn gluten meal	40
Dried carrots	30
Dried sweet potatoes	24
Yellow corn	10
Barley	2
Millet	2
Wheat	1.5
Oats	1.0
Soybean meal	1.0
Milo	0.7
Dried tomato pomace	0
Cottonseed meal	0

highly concentrated source of biologically available xanthophyll containing 30 times as much as the same quantity of dehy. Florafil contains 5.4 gm of xanthophyll per pound. Corn endosperm oil is also a color additive. It is a reddish-brown liquid composed chiefly of glycerides, fatty acids, sitosterols, and carotenoid pigments obtained from the gluten fraction of yellow corn.

An equal quantity of xanthophyll from different sources does not produce identical results. The main factor involved is the digestibility of the ingredient which supplies the xanthophylls. The xanthophyll present in yellow corn, algae meal, and Florafil is well utilized by poultry. Lettuce with a high vitamin E content shows good utilization of carotenoids for yolk pigmentation.

Pigmentation carries a price tag so it is necessary to compromise between color and the cost of poultry meat and eggs. It is not necessary to have a continuous supply of xanthophylls in broiler feeds; the important time is during the final finishing period of a few weeks. Pigmentation of healthy birds of yellow-skin varieties can be obtained with 10 mg xanthophyll per pound of feed. As the quantity of xanthophyll is increased in the feed, a plateau is reached at 25 mg. Xanthophyll contents of various feedstuff are given in Table 18.5.

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Carbohydrates

INTRODUCTION—NATURE OF CARBOHYDRATES

Carbohydrates include starch, cellulose, sugar and related substances, and compounds composed of carbon, hydrogen and oxygen with the latter two elements in the same proportion as in water. These make up about ¾ of the dry matter of plants and are the chief source of energy in poultry rations. Starch and sugars are easily digested by poultry and have a high feeding value. Cellulose, the complex carbohydrate which forms the woody fiber of plants, is poorly digested and has a low value for poultry. Green plants build simple carbohydrates from carbon dioxide from the air and water from the soil through the action of chlorophyll in the leaves. The energy to produce carbohydrates comes from the sunlight absorbed through the plant tissue. Carbohydrates arise from photosynthesis, the most important chemical reaction in nature, as follows:

$$6\,CO_2 + 6\,H_2O + 673\text{ Cal} = C_6H_{12}O_6\,(\text{glucose}) + 6\,O_2$$

Various members of subgroups of carbohydrates have different structural formulas and exhibit different degrees of optical activity (Table 19.1). The ability to rotate the plane of polarized light is an important distinguishing feature of the sugars, some of which are stereoisomers of each other. From the simple organic compound, plants can form more complex materials. Simple sugars contain 5 or 7 carbon atoms in each molecule. The former are pentoses which form mainly parts of the complex carbohydrates; the latter are hexoses, such as glucose, fructose, and galactose.

Sugars containing an aldehyde or ketone group have a reducing power which classes them as reducing sugars. The glucose which occurs in nature has the D configuration which accounts for its other name, dextrose. Glucose is of interest because it is the principal end product of the digestion of higher carbohydrates, and it is the form in which these nutrients circulate in the blood and when utilized, furnish energy.

The union of two molecules of hexoses produces cane sugar (sucrose), maltose, or lactose, the sugar in the milk of all mammals. Polysaccharides are complex carbohydrates formed by the union of a great number of molecules of simple sugars with the elimination of water. They differ decidedly in physical properties from the simple sugars, being insoluble in water and forming sticky gelatinous solutions.

TABLE 19.1

CARBOHYDRATES IN FEEDS

Monosaccharides
- Dimethyldioses ($C_4H_8O_2$)
  - Dimethylglycolose, $CH_3 \cdot CHOH \cdot CO \cdot CH_3$—occurs in vinegar
- Trioses ($C_3H_6O_3$)
  - Dioxyacetone, $CH_2OH \cdot CO \cdot CH_2OH$—fermentation product
- Oxymethyltetroses ($C_5H_{10}O_5$)
  - Apiose or beta-oxymethyltetrose $(CH_2OH)_2 \cdot COH \cdot CHOH \cdot CHO$—a constituent of the glucoside apiin of parsley
- Pentoses ($C_5H_{10}O_5$)
  - l-arabinose, $CH_2OH \cdot HOCH{:}HCOH \cdot HOCH \cdot CHO$—formed by hydrolysis of araban
  - l-xylose, $CH_2OH \cdot HOCH \cdot HCOH \cdot HOCH\text{-}CHO$—formed by hydrolysis of xylan
- D-ribose, $CH_2OH \cdot HOCH \cdot HOCH \cdot CHO$—constituent of nucleic acids
- *Methylpentoses* ($C_6H_{12}O_5$)
  - Rhamnose, $CH_3 \cdot CHOH \cdot HCOH \cdot HOCH \cdot HOCH \cdot CHO$—constituent of glucosides
- Fucose, $CH_3 \cdot CHOH \cdot HOCH \cdot HOCH \cdot HCOH \cdot CHO$—formed by hydrolysis of fucosan of seaweeds
- Hexoses
  - D-Glucose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HCOH \cdot HOCH \cdot CHO$
  - D-Mannose, $CH_2OH \cdot HCOH \cdot HOCH \cdot HCOH \cdot HCOH \cdot CHO$—in plant juices formed by hydrolysis of mannan
  - D-gallactose, $CH_2OH \cdot HOCH \cdot HCOH \cdot HCOH \cdot HCOH \cdot CHO$—constituent of glucosides and formed by hydrolysis of lactose
  - D-fructose, $CH_2OH \cdot HOCH \cdot HOCH \cdot HCOH \cdot CO \cdot CH_2OH$
  - D-sorbase, $CH_2OH \cdot HCOH \cdot HOCH \cdot HCOH \cdot CO \cdot CH_2OH$—in fermented juice of *Sorbus domestica*

Disaccharides ($C_{12}H_{22}O_{11}$)
- Sucrose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5$—in sugar cane, sugar beets, and many natural products
- Maltose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + H_2O$—formed by the action of malt extract on starch
- Trehalose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + 2\,H_2O$
- Lactose, $C_6H_{11}O_5 \cdot O \cdot C_6H_{11}O_5 + H_2O$—the carbohydrate of milk

Trisaccharides ($C_{18}H_{32}O_{16}$)
- Raffinose (melitriose or gossypose), $C_6H_{11}O_5 \cdot O \cdot C_6H_{10}O_4 \cdot O \cdot C_6H_{11}O_5 + 5\,H_2O$—occurs in beet juice and cottonseed

Polysaccharides—*To this group belong xyland and araban, both assigned tentatively the* formula ($C_5H_8O_4$) which are widely distributed in nature and are the mother sub*stances of the pentoses xylose and arabinose, respectively, also starch, dextrin,* mannan, the mother substance of mannose, glycogen, and cellulose with the general formula ($C_6H_{10}O_5$). The pectins derived from the middle lamellae of many fruits are closely related substances.

STARCH

Starch is the chief carbohydrate in plants and when hydrolyzed produces many molecules of glucose. Most plants store their reserves principally as starch deposited in the form of starch grains which have a characteristic size and shape. Seeds are rich in starch, especially the cereal grains which contain 60% or more. Starch is insoluble in water and, therefore, must be changed to sugar by an enzyme before it can be carried from one part of

the plant to another. There is little starch in the bodies of animals, except a small amount stored in the form of glycogen or animal starch, chiefly in the liver. An acidified starch solution upon heating produces dextrins which are simpler in structure. If the treatment is continued, maltose will be formed and eventually glucose.

CELLULOSE

Cellulose and related compounds make up the cell walls of plants. Cellulose is not a single chemical substance but includes a group of related substances more complex than starch and very insoluble. As plants mature, the percentage of cellulose in the stems and leaves increases. Cellulose can be digested by animals only through the action of bacteria, as in the stomach of cattle and sheep. For poultry, it has little value, being digested only to a very limited extent. The more fibrous parts of plants also contain hemicelluloses, formed from both the 5 and 6 carbon sugars, and lignin which is less digestible than cellulose and whose chemical structure is not known. In feeds, carbohydrates are separated into two classes of substances, crude fiber and nitrogen-free extract. The former is composed of relatively insoluble carbohydrates such as cellulose; the latter are more soluble and include starch, sugars, organic acids, the soluble pentosans, and other complex carbohydrates.

UTILIZATION OF CARBOHYDRATE

Energy from sunlight is liberated when carbohydrates are eaten, digested, and oxidized in body tissues. They serve as a source of heat and energy in the body. A surplus taken into the body is transformed into fat as a reserve supply of heat and energy. An examination of starch grains under the microscope can determine their source. Fiber is determined by boiling a dry, fat-free sample in dilute acid, washing it free of acid, boiling it in dilute alkali, and washing. The dry solid residue remaining is termed "crude fiber." Nitrogen-free extract consists of the digestible portion of the more complex carbohydrate.

When starch is hydrolyzed with acids or enzymes it is changed to dextrin, maltose, and finally into glucose. It consists of a linear chain of glucose units combined with a branched chain of these units. Starch gives a characteristic blue color with iodine. The woody parts of plants such as cobs, hulls, and fibrous portions of roots and stems contain a complex indigestible substance called lignin in which the proportion of carbon is much higher than in carbohydrates. Lignin is important because of its dominant influence on the degree of digestibility of many feeds.

Carbohydrate is broken down to simple sugars under the action of spe-

cific enzymes secreted into the digestive tract. The principal end product is glucose. The breakdown of cellulose and similar compounds is accomplished in ruminants not by enzymes secreted into the digestive tract, but rather by enzymes of symbiotic microorganisms. Anatomical differences in the digestive tract explain why hay and other roughages can form such a large part of the rations of cattle and yet be tolerated in only limited amounts by chickens. The crude fiber of growing pasture grass, fresh or dried, is more digestible than that of mature hay, due to the presence of lignin deposited in the cell wall within the hay. Lignin is not only indigestible itself, but it also lowers the digestibility of the cellulose and other complex carbohydrates.

An important factor governing the bulk of the ration is the crude fiber. A quart of cornmeal weighs 1½ lb, whereas oats weigh approximately 1 lb to the quart. Increasing the fiber content of the ration increases its bulk. Feeds high in crude fiber tend to be laxative. The ability of the liver to store sugar as glycogen is limited and thus when carbohydrate intake regularly exceeds the current needs of the body for energy purposes, sugar is transformed into fat.

Pyruvic acid is the common intermediate in the catabolic and anabolic reactions of carbohydrate. Various vitamins are concerned in the enzyme systems involved in the intermediate metabolism of carbohydrates.

According to scientists at the University of Missouri, glucose rather than starch has an effect on reproductive performance of hens fed purified diets. Glucose reduced hatchability; and lower body weights and lower fertility were found when compared to results when starch was the principal carbohydrate source. Also, sucrose-fed hens had a great deal of abdominal fat.

CARBOHYDRATE BY DIFFERENCE

The difference between 100 and the sum of the crude protein, fat, moisture, and ash is called "total carbohydrate" or "carbohydrate by difference." In addition to the true carbohydrates, this "difference" may include such compounds as organic acids. Foods of animal origin, except milk products, contain little carbohydrate; whereas foods of plant origin have a variety of carbohydrates—starch, sugars and cellulose as well as appreciable amounts of pentosans, dextrins, gums, and other carbohydrates. About 97% of the carbohydrates in flours and meals are starch, dextrin, and sugar with a small amount of fiber. In fruits, a large proportion of the carbohydrate is sugar, especially monosaccharides, along with some starch, cellulose, and pentosans. The main carbohydrate of animal source is milk sugar.

TABLE 19.2

THE INOSITOL CONTENT OF BIOLOGICAL MATERIALS

Material	Inositol Content, Gamma per Gm of Fresh Tissue
Cereals	
Wheat germ	6000
Whole wheat	1700
Flour, white	830
Flour, whole wheat	1105
Oats	1000
Corn	500
Vegetables	
Peas, English, green	1620
Cabbage	950
Potatoes, sweet	660
Potatoes, white	290
Lettuce	550
Carrots	480
Spinach	270
Miscellaneous	
Peanuts, roasted	1800
Molasses	1500
Tea leaves, dry	10,000
Yeast, *Torulopsis utilis*	2700
Yeast, brewers	500
Meats	
Beef, muscle	115
Beef, heart	2600
	16,000
Beef, brain	6000
	2000
Beef, liver	3400
	510
Pork, loin	360–450
Veal chop	320–350
Fowl and Fish	
Chicken, breast	480
Oyster	440
Halibut	170
Salmon	170
Egg	220
Milk products	
Whole milk, cow's	500
Cheese	250

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Water

ITS GREAT IMPORTANCE

Poultrymen frequently neglect good water management. If water cost more perhaps poultrymen would appreciate its true value. The amount of water that birds drink depends on several factors: amount and kind of feed, size of the bird, rate of lay, environmental temperature, water temperature, and chemical content of the water. Birds must have sufficient water to perform satisfactorily and, therefore, water should always be readily available

TABLE 20.1

WATER CONSUMPTION OF POULTRY

Age of birds (Weeks)	Broilers and Replacement Flocks	Turkeys (Gal.)
	(100 Birds)	
1–3 days	6–8 qt	1.1–2.5
3 days–3 wk	6–8 qt (automatic waterers may be started at 2 wk)	. . .
4–7	. . .	3.7–8.4
4–6	2–3 gal.	. . .
6–12	3–6 gal.	. . .
9–13	. . .	8.8–14.2
12–14	6–8 gal. (increase to 9 gal. if temp is 90° F or higher)	. . .
15–19	. . .	16.7
21–26	. . .	13.5–17[1]

[1]Varies according to weather

TABLE 20.2

WATER CONSUMPTION OF LAYERS

% Production	Gal. of Water per 100 Birds per Day
0	3.7
10	4.1
20	4.4
30	4.8
40	5.1
50	5.4
60	5.8
70	6.1
80	6.5
90	6.8

(Table 20.1). *Unlike larger farm animals, birds drink small amounts of* water many times a day.

Water enables poultry to carry on normal body functions. It softens the feed for digestion, aids in assimilation, helps eliminate waste products, aids in controlling body temperature and serves as a lubricant for joints, muscles, and body tissues. Over half of the adult bird's body is composed of water. It is higher in young birds, up to 78% at hatching time. Eggs are ⅔ water (Table 20.2).

Sources

Birds obtain water in two ways. First, as drinking water they put their beaks in the water rather deeply and raise their heads horizontally. The water trickles into the throat by gravity and is swallowed. That is why waterers are placed at the height of the bird's back. Birds also get water from their feed—even air-dry feeds contain 8 to 12% water. When feed is utilized in the body, its hydrogen combines with oxygen to produce water. For every 10 oz of fat a bird burns, it produces 10.7 oz of water.

Birds cool themselves by drawing air through their lungs into air sacs which surround their internal organs. Some of the water that the birds drink evaporates into the air the birds exhale. It takes heat from the birds to cause evaporation. Therefore, when birds exhale air containing evaporated water, they also exhale heat, and this reduces body temperature. If birds have free access to water and are exposed to extremely high temperatures, they survive three times as long as those without water. Water consumption at 100° F is double that consumed at 70° F. Thus, during periods of high temperatures, access to water is especially important. Layers prefer water within the range of 50° to 55° F, about the temperature it comes from most wells.

Water intake is greatly reduced when its temperature reaches 90°–95° F. Birds will not drink at all when its temperature reaches 112° F. Very cold water also reduces its consumption. During winter when the water is warmed to 50° F it increases as much as 25%. If water supply is cut off, digestion is hindered and excretion limited.

An Ample Supply is Necessary

When restricted in water intake, laying hens drop out of production at about the fifth day. Production will return to the former levels if the deprivation is for only 36 hr. Week-old chickens deprived of water for less than 24 hr are not in serious trouble, but beyond that period birds do not completely recover by 42 days. Water and feed consumption figures for average conditions are given in the accompanying table. Broilers consume twice as much water as feed. There is no surer way to stop egg production

than to cut off the supply of water. Water must be kept from freezing in cold weather and an additional supply is needed on hot days. Provision to keep water from freezing in the winter includes electrically heated fountains, immersion-type heaters, and light bulbs underneath the waterer.

Purity of Water

Water must be of satisfactory purity, and free from harmful bacteria, excessively dissolved or suspended solids, unpleasant odors, and tastes. Sanitation is an important part of good water management. Surface drainages sometimes permit organisms to get into water supplies and cause disease. *Salmonella* type organisms are the most serious offenders in most instances.

Continuous-flow, watering systems should be cleaned at least three times weekly with a stiff-bristled brush. Flush the troughs with a disinfectant such as quaternary ammonia or cresylic acid. Carefully flush the disinfectant out of the troughs or it will poison the flock. The amount and kind of various mineral salts in solution in water should be checked. The carbonates, bicarbonates, chlorides, and sulfates of sodium, potassium, magnesium, and calcium occur most commonly. Certain sources of water contain such high percentages of mineral that they are unsuitable for poultry. Over 1,000 ppm of various minerals cause problems. Very high levels of salt in the water cause prolapse.

Hardness of Water

Hardness of water is due to dissolved salts and is expressed in ppm of calcium carbonate or grains of hardness per gallon. A grain of hardness is equivalent to 17.5 ppm. Soft water contains 15 to 50 ppm and is preferred by poultry; hard water contains from 150 to 200 ppm. High levels of iron in water can be a problem due to its staining characteristics. Even 3 ppm can be objectionable. Water treatment can remove calcium, magnesium, and iron. A high nitrate content in water is serious. It produces acute poisoning or interferes with the utilization of nutrients. Animals are unable to efficiently convert carotene into vitamin A, thus feed has to be supplemented with a free form in vitamin A. The presence of nitrites and ammonia in surface waters indicate contamination with drainage from barns and outhouses and possibility of the presence of pathogenic microorganisms.

Controlled Watering Systems

Some poultrymen control water consumption to keep the laying house drier and the droppings in better conditions. Controlled watering systems are used to prevent overconsumption and reduce water wastage. Controlled watering systems may save as much as 4½% of the feed over continuous

flow systems, since feed is washed away in the watering troughs. For trough watering systems, water is turned on for 30 min and off for 90 min. In other words, the birds have free access to water 30 min out of every 2 hr. This watering program will not affect egg production providing the temperature does not exceed 90°F and humidity does not exceed 55%.

Plenty of clean, fresh water in clean equipment placed where the animals can reach it conveniently helps cut cost of egg production. Rain water, the purest form of natural water contains trace amounts of the gases normally present in the atmosphere. Pond water and other surface water contains from 2 to 500 ppm of dissolved minerals, and underground water from 200 to 350,000 ppm, depending on the nature of the geological formation through which it has passed.

The importance of water is emphasized by the high percentage of the body of the chicken and the content of the egg that consists of this substance. About ⅔ of the chicken's body and ⅔ of the egg is water. Most nutrients are absorbed from the digestive tract in water solution. Water is a major part of the blood and, therefore, essential in the transport of nutrients within the body. It acts as a lubricant for joints and muscles and helps stabilize body temperature. It is necessary for elimination of waste products from the body.

Water Management for Poultry

Water is also involved in the management aspects of poultry enterprises. Wet droppings from birds produce a mess that is difficult to clean. Most poultrymen strive to prevent excessive water intake so that the droppings are rather crumbly. A number of factors affect the moisture content of droppings. Hens in heavy production tend to produce watery droppings. Birds consuming an excessive amount of water will have watery droppings. Certain cage birds because they have nothing else to do may just drink water with the result their droppings are much wetter than in the case of floor birds. The salt content of the feed or the salt content of the water may produce a flushing action.

Certain ingredients, e.g., fishmeal and fish solubles, have a laxative effect. Sometimes fish is preserved by salting. This salt is still in the fish when it is processed into meal and produces rather high levels of salt in some lots of fishmeal or fish solubles. Increasing the protein content of the feed and decreasing the energy content of the feed also increases the water content of droppings. Some strains of birds tend to have more watery droppings than others. The presence of algae in drinking water will increase watery droppings. If the birds get enteritis, they have watery droppings. The physical form of the droppings is of economic importace to the poultry industry.

In order to prevent sloppy manure, some poultrymen restrict the bird's

drinking water. Cage birds are allowed to eat for an hour before they receive water and they are given the last water about an hour before the lights go out at night. Water is supplied 5 times a day for about 15 min. With that restriction, it is claimed there is ⅓ less moisture in the manure. Other poultrymen believe that birds should have plenty of water at all times. Apparently some birds start to drink before they eat their food and there is nothing to stop this water from going straight through the gut to produce watery droppings.

Contaminants Found in Water

Usually drinking water contains very few contaminants, however contamination occurs occasionally in certain parts of the country. Substances which prove toxic are fluorine, molybdenum, selenium, nitrate, and other specific trace substances in relatively heavy concentrations. Water contamination may also occur from commonly used household detergents. As little as 0.5 ppm of detergent in the drinking water causes undesirable taste and foaming.

Infectious diseases can be transmitted through drinking water. Among these are coccidiosis, salmonellosis, leptospirosis, brucellosis, and bovine tuberculosis. Ducks perform well with fairly high *E. coli* contamination in the water while chickens are depressed in weight under the same conditions. Turkeys have a higher tolerance for nitrates than cattle. Generally acceptable drinking water for poultry should be free of hydrogen sulfide, seleniferous gases, and ammonia, as well as low in *E. coli* count, total nitrates, and nitrites. Temperature of water affects voluntary intake to a great extent. Poultry prefer water with the chill taken off when they are in a cold environment, and cool water when the surrounding air temperature rises above 75° F.

Water supplies are frequently tested to see if coliform bacteria are present. These bacteria are found in fecal material and are rather easy to test for. If coliform bacteria are found in a particular water supply, it is presumptive evidence that the water is being contaminated by fecal material.

Water Intake

The intake of water depends primarily on the amount of food eaten, but there are considerable individual differences in the amount of water intake by the birds. The quantity of salts ingested, temperature, output of water by way of the kidneys and gut, as well as through respiration and aspiration through body surfaces affect water intake. Chickens, like ducks and certain marine birds, have a salt excretion gland. This permits birds to concentrate salt in a gland in the head of the bird. This is a means by which birds can excrete salt almost in solid form. The amount of water con-

sumed is regulated and influenced by a thirst center and another one in the brain which stimulates the releasing of the antidiuretic hormone, which decreases excretion of water by kidneys. Fatty tissue contains less water than leaner tissue.

Water intake can have quite an effect on the rate of egg production. Where no water was experimentally given to birds in production for 3 days all hens stopped laying by the 5th day and it took a month for these birds to get back into top production. Thus, the effects of a water shortage show up after a few days. A lack of water, even for a short period of time can seriously hamper rate of production. With some birds, 2 hr without water produced a noticeable effect; others were not as seriously affected. Birds should be provided more water than they need. Dried feedstuffs contain about 10% water and artificially dried feeds like alfalfa meal much less.

Availability of Water

There is an enormous quantity of water on the earth but relatively little of it is drinkable. Water in the ocean is not suitable for drinking since it is high in minerals. Minerals can be removed but this is expensive. Where water is impounded in a lake without an outlet, such as Salt Lake, salinity may develop up to 350,000 ppm. The palatability of water is greatly enhanced by the presence of carbon dioxide as shown by the popularity of carbonated drinks. Rain water or water that is boiled has a flat taste due to lack of carbon dioxide. There are 30 or more mineral salts present in surface or deep well waters and of these most are carbonates, bicarbonate, chlorides, and sulfates.

In the Midwest, certain places have alkaline water. It contains sodium and calcium carbonate at levels around 5,000 ppm. Animals build up their tolerance to such waters, but feed efficiency is reduced while they are developing tolerances. Poultry is much more susceptible to minerals dissolved in water than in the feed.

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Nutrient Interrelationships

PART 1 Interactions

One of the most confusing areas of nutrition is that of interactions and interrelationships. The complexity arises from the fact that interactions can occur among different mineral elements and between certain minerals and organic compounds. The site of these interactions ranges from the level of the intestinal tract to that of enzymatic action. If some nutrient is in excess, almost invariably the animal will perform abnormally.

INTERRELATIONSHIPS BETWEEN MINERALS

Historically, one of the first relationships of nutritional significance was observed between calcium and phosphorus; magnesium was later shown to be related to the utilization of these two minerals. Calcium utilization is favorably influenced by an adequate level of dietary vitamin D and phosphorus, and impaired by an excess of magnesium or oxalate in the diet. Diets high in protein significantly favor the absorption of both calcium and magnesium. Since a slightly acetic intestinal pH favorably influences the absorption of calcium, lactose (which promotes the establishment of an aciduric bacterial flora) is an important dietary factor in calcium utilization. In order to be utilized properly, calcium and phosphorus must be in the ration in a proper ratio. Excess calcium interferes with the utilization of zinc, manganese, and other nutrients.

In the young growing bird calcification requires intake of calcium, phosphorus, and vitamin D. Certain fatty acids exert a slight antirachitic value, thus reducing the requirements of vitamin D. Proper balance of calcium and phosphorus minimizes the vitamin D requirement. Similarly an excess of vitamin D permits calcification with borderline mineral levels or with an adverse ratio of calcium and phosphorus. Thus, it is impossible to state a specific requirement for 1 of these nutrients without defining the levels of the other 2. Elemental sulfur interferes with the absorption of vitamin D and probably other factors. Large amounts of iron, manganese, and other minerals form highly insoluble phosphates, and thus cause rickets. Phosphorus, present in most plant sources as a phytate, is only partially utilized for bone formation but extra vitamin D improves its availability.

In the case of trace minerals, copper and molybdenum counteract each other. Arsenicals counteract the toxicity of excess selenium. Chelating agents including sugars and amino acids have an important bearing on the availability of minerals, particularly zinc.

Copper is necessary for the utilization of iron. The need of copper for iron to be effective in the prevention of anemia is well established, but little is known of the biochemistry through which this interaction works. It is apparent that no requirement can be stated for either element without specifying the level of the other. Copper is in some way primarily involved in erythrocyte numbers and survival time, and iron with hemoglobin concentration within the cell.

Molybdenum influences copper absorption and sulfur or sulfate is involved in the copper-molybdenum interrelationships. Experimental data illustrate the complexity of the interrelationships existing between minerals. Minerals may interact not only amongst themselves, but also with the vitamins, proteins, and other factors within the diet. Sites of mineral interrelationships may be in the diet or intestine and at the cellular level.

SYNERGISM BETWEEN VITAMINS

As our knowledge of vitamins developed, it became increasingly evident that these substances are important components of enzymes which function in cyclic systems serving to metabolize carbohydrate, fat, and protein. The amount of dietary fat affects vitamin requirements, high fat diets reduce the thiamine requirement, and raise the riboflavin requirement.

The choline requirement of the animal is increased as the fat content of the diet is increased. Synergism between vitamins occur. Vitamin E promotes the efficient utilization of vitamin A. Vitamins A and D are the only vitamins that produce distinctly deleterious effects from unbalanced overdosing, although the levels involved are beyond that which may be expected in routine usage. While it is true that malnutrition can be caused by excesses of certain nutrients, it is unlikely that reasonable uses of vitamins in the fortification of feeds would be detrimental.

So-called toxic effects resulting from the addition of an excess of individual amino acids to diets may be due to an amino acid imbalance or antagonism between two amino acids.

The effect of source of protein on the requirement for zinc is established. Proteins alleviate the effects resulting from excess levels of copper, and in this case, casein is as effective as soybean protein. The component of proteins that affects the utilization of certain trace minerals is phytic acid. The effect of phytic acid in decreasing the zinc and iron availability is primarily by the physical and chemical properties of the dietary constituents in the gut rather than by any effect of phytic acid at the cell level.

These examples of trace mineral interrelationships point up the importance of carefully balancing the various mineral constituents in the ration to insure maximum gains and feed efficiencies. The major cause of pellagra is a concurrent deficiency in corn of niacin and tryptophan.

As emphasis has shifted over the years in the study of nutritional biochemistry among calories, protein, minerals, vitamins, carbohydrates, and amino acids, interrelationships of various sorts have become evident. One cannot change levels in one area without producing shifts and changes in another.

Various nutrients, both organic or inorganic, are so dynamically interrelated in metabolism that their quantitative requirements are also interdependent. Balance is conceived primarily as having enough of a given element in a ration but a balance can be upset and nutrition unfavorably affected by having an excess or too little of a given ingredient thus causing an imbalance. This occurs sometimes where additions are made beyond any demonstrated needs as insurance or on the basis that intakes beyond such needs have important plus values in terms of health and long-term productivity. Actually, the reverse may be true for certain nutrients because of the imbalances created.

ROLE OF TRACE ELEMENTS

Increased interest in the role of trace elements in poultry nutrition has been stimulated by reports on the possible nature of the active component in unidentified growth factor supplements.

A natural copper deficiency is encountered in peat and muck soils in Florida, England, the Netherlands, Australia, New Zealand, Czechoslovakia, and Finland. Peat soil areas of the world produce native forages in quantities unmatched in other soil types and it is necessary to add minor minerals to the soil to maximize production. In addition to copper, such elements as manganese, zinc, phosphorus, potassium, and boron are also needed, but copper provided the keystone that opened these areas to exploitation. Where fertilization is not used, "muck sick" animals developed symptoms such as severe anemia (often blamed on parasites), rapid loss of weight, diarrhea, acra matricia, fragile bones, fecal abnormalities, and quick death. There is good evidence that the interactions between molybdenum and copper are mediated by inorganic sulfate. Poultry's requirement for copper, cannot be determined until the influence of other elements, such as molybdenum, is determined. Depending on the level of inorganic sulfate in the diet, the action of molybdenum upon copper may be quite different. The multiple interrelationships which exist between copper, sulfur and molybdenum, and phosphorus also include other mineral elements.

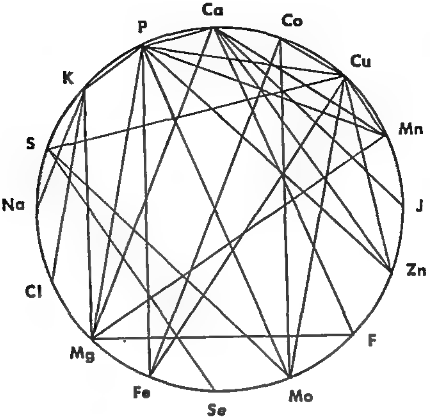

FIG. 21.1. MAJOR AND TRACE MINERAL DIETARY INTERRELATIONSHIPS ARE INDICATED; THESE INFLUENCE SPECIFIC REQUIREMENTS AND TOLERANCE TO EXCESSES

Inverse Relationship Between Copper and Zinc

There is an apparent inverse relationship between copper and zinc. A high level of copper in the liver, such as occurs in copper toxicity, results in almost complete elimination of zinc from liver tissue. The mechanism involved is apparently within the animal body as opposed to the digestive tract.

Importance of Calcium and Phosphorus Balance

Pullets fed growing rations with an improper balance of calcium and phosphorus that allows surplus calcium to be excreted develop necrosis or degeneration of the kidneys at the time they go into the laying house. In addition, birds show lesions of dehydration, muscular hemorrhages, increased intestinal mucous, and such kidney changes as enlargement and loss of color. Urate deposits are present in the kidneys, joints, and pleura as well as the protective membranes around the lungs. Microscopic examination of tissues of birds with necrosis indicate that the parathyroid gland is wasting away. Mortality during both the growing and laying period is increased. A wide ratio of calcium and phosphorus starting at 12 weeks of age causes mortality during the growing period, poor egg production and infectious bronchitis occurs either from vaccination or from natural ex-

posure. To reduce necrosis, starter and growing rations should not contain more than 1% calcium. Calcium can be increased somewhat in the late growing period without harm but pullets can build up calcium reserves very rapidly just before beginning to lay. It is desirable to change to high calcium layer feed after production reaches 5 to 10%. Thus, feeding rations with wide calcium:phosphorus ratios during the growing period cause permanent damage to the kidneys. Thus, a calcium-phosphorus imbalance sometimes shows up at a later time.

Need for Manganese

Manganese is needed to prevent a crippling disease known as "perosis" or "slipped tendon," which affects the intertarsal or hock joint of the chicks and turkey poults. It is characterized by an enlargement and flattening of the bone in the hock joint and a slipping of the tendon of Achilles out of its chondyle in such a way that the metatarsis is pulled to the side and can no longer support the weight of the chick.

Effect of Choline Deficiency

Choline deficiency produces the same symptoms. Even when the diets are adequate in manganese and choline, severe crippling and enlargement of the hock joint in chicks and poults occur due to a deficiency of niacin or zinc. This crippling is not due to changes in calcification of the bone but to improper natural maturation of the cartilaginous matrix in which the bone is deposited. Although different kinds of biological changes take place, depending upon the nutrient that is in short supply, nevertheless, in the long run the deficiencies all produce the same crippling effect.

When chicks are fed a purified diet containing casein as a source of protein, the zinc requirement is only 15 mg per kg of diet. However, if the casein is replaced by an isolated soybean protein, the zinc requirement in the new diet is over 30 mg per kg of diet. The zinc requirement of chicks fed isolated soybean protein diet can be reduced by adding ethylendiaminetetraacetic acid (EDTA), an effective chelating agent, to the diet.

Vitamin E acts in some instances simply as an antioxidant and in other instances, it has a more specific role in metabolism. Recent research on liver necrosis and oxidative diathesis has led to the discovery that selenium is interrelated with vitamin E for the prevention of a number of vitamin E deficiency diseases. Muscular dystrophy can be produced in chicks by feeding a diet deficient in vitamin E, selenium, and sulfur-containing amino acids, especially cystine. If this diet is supplemented with vitamin E alone, results indicate the existence of an important interrelationship between vitamin E, selenium, and sulfur-containing amino acids in muscle metabolism. Vitamin A and vitamin E are readily oxidized in animal feeds.

Vitamin E, however, is more readily oxidized than vitamin A and consequently serves as an antioxidant until it is used up protecting vitamin A from oxidative destruction. Hence, the addition of vitamin E to a feed spares the dietary level of vitamin A by protecting the vitamin A from oxidation.

An important function of choline is to supply labile methyl groups which most animals can synthesize only to a limited degree. The requirement for choline is reduced when vitamin B_{12} and folic acid are supplied in adequate amounts, since these are involved in the metabolic synthesis of methyl groups. Betaine, and to some extent methionine, provide methyl groups and thus reduce the dietary requirement for choline. Conversely, the dietary requirement for vitamin B_{12} is influenced by the levels of choline and methionine. High fat levels in feeds increase the need for choline since choline is involved in fat transport in the body as a part of the phospholipid, lecithin. Very high levels of niacin can increase the need for methyl groups also.

Action of Antibiotics

In general, the addition of the commonly used antibiotics at the levels used for growth stimulation tend to spare the dietary requirement of the animal for certain B-complex vitamins. This action may be due to the bacterial flora on the intestinal tract: (1) by increasing the numbers of microorganisms which synthesize vitamins; (2) suppression of microorganisms which may actively compete with the host for certain nutrients; and (3) suppression of microorganisms which may interfere with the absorption of vitamins from the intestinal tract into the bloodstream or possibly the reduction of microorganisms which produce toxic reactions thus creating greater metabolic needs of the host for certain nutrients. Possibly more than one of these modes of action of antibiotics is operative under most conditions. Continuous high level feeding of certain drugs, including sulfaquinoxaline and arsanilic acid, increases dietary requirements of the chicks for vitamin K.

Supplements are sometimes used in dosing an animal in an effort to insure that nutritional requirements are adequately met. Such mixtures are particularly dangerous when used indiscriminately and over considerable periods of time. The studies of the relationship of calcium with zinc is a practical example. Increasing the calcium levels to insure adequate intakes of calcium results in a change in availability of zinc and manganese. Understanding these differences provides the key to better nutrition for poultry under the varying dietary conditions in the world today.

Trace elements are essential in some 26 enzymes in animals and plants and constituents or activators. On a niacin-low diet excess threonine inter-

feres with the formation of niacin from tryptophan in such a way as to limit growth markedly.

When iron is chelated with an amino acid it appears to enter the reticulo site readily and hemoglobin synthesis takes place rapidly. Cystine and histidine have marked metal-binding properties.

THE NEED FOR NIACIN

Niacin, through its two important enzymes, DPN and TPN, takes part in anaerobic and aerobic oxidation of glucose in fat metabolism, in the degradation and synthesis of amino acids, and the oxidation of amino acid residues. It is easy to see, therefore, why the requirement of this vitamin is interrelated with those for a number of other essential nutrients.

EFFECT OF SELENIUM

Poultry is susceptible to selenium poisoning; growth, egg production and hatchability are decreased below the normal level by feeding a ration high in selenium. Selenium is found in plants which obtain it from the soil. Seleniferous grains are obtained in South Dakota and Wyoming. Arsenic counteracts the toxic effects of selenium. With respect to hatchability of eggs, arsenic-selenium antagonism cannot be explained on the basis of impaired absorption or increased excretion of selenium. It is thought that arsonic acid aids in the inhibition of succinic dehydrogenase brought about by selenium.

Thus, the study of nutrition has progressed from simple determinations of specific nutrient requirements to a necessity for understanding the interrelationships between the various nutrients and the effects of the level upon the requirement for the other. Complex interrelationships of trace elements in animal nutrition make it difficult to evaluate dietary requirements of isolated components of a nutritional mixture, unless such relationships are considered.

In the animal, these elements interact in metabolic reactions so as to spare or increase the need of other elements and they profoundly affect the presence of other trace elements and micro- or macroelements. The newer knowledge of nutritional interrelationships throws new light on the conflicts and differences in research findings.

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INTRODUCTION

The nutritionist must avoid materials that might be harmful. He should become acquainted with possible sources of toxins and with the symptoms and lesions produced by these materials. Specific deficiencies can be created by the presence of unidentified substances occurring in natural feedstuffs. It is one thing to provide a ration containing all the required nutrients in pure form at required levels and quite another problem to formulate a perfect ration from natural feedstuffs. In the latter case, not only must specific deficiencies be accounted for, but adjustment must be made for the presence of things known and unknown which alter the delicate balance of nutritional equilibrium. Growth-inhibiting factors are present in some ingredients.

ANTIMETABOLITES

In 1940, Woods discovered that the bacteriostatic action of sulfanilamide could be reversed in a competitive fashion by *p*-aminobenzoic acid. Thus, *p*-aminobenzoic acid, a close structural analogue of sulfanilamide is an antimetabolite of the latter.

Characteristic signs of vitamin deficiency diseases can be produced by the administration of a suitable structural analogue of a particular vitamin. The syndrome can be prevented by increasing dietary intake of the vitamin. The symptoms produced by the structural analogue occur while the animal is consuming an otherwise adequate diet. Though no deficiency is present in the ration, one is created in the animal by the antimetabolites. Since the signs resemble those which result from a simple deficiency, and since they are obliterated by increases in the intake of the vitamin, it is clear that the antimetabolite is creating a specific deficiency disease. Except for vitamins A, D, and B_{12}, antimetabolites of each of the vitamins have been produced and studied. For example, when pyrethiamine is fed to mice receiving an adequate, purified diet, typical manifestations of athiaminosis are called forth. These can be prevented by administration of extra thiamine.

Years ago, wheat flour was treated with nitrogen trichloride in order to improve quality. However, wheat treated in this fashion caused "running fits" in dogs. The toxic substance in the flour was identified as methionine sulfoximine. It arises from the reaction of nitrogen trichloride on methionine within the proteins of wheat.

The effects of methionine sulfoximine are overcome by methionine, and thus it is an antimetabolite of this amino acid. Although no ill effects oc-

curred in humans as the result of consuming flour bleached with nitrogen trichloride, the flour industry promptly changed its bleaching agent.

Dicoumarol is the causative factor of the hemorrhagic sweet clover disease. Microbial action on coumarin normally present in sweet clover leads to the formation of a poisonous substance. Because the manifestations of the hemorrhagic disease are quite similar to the signs of vitamin K deficiency, attempts were made to prevent the disease with this vitamin and these proved successful.

Preliminary work has suggested that the time-honored association of a corn diet with the existence of pellagra may result from the presence of an antagonist of nicotinic acid in this food. Extract has been prepared from corn which depresses the rate of growth of mice maintained on a diet low in protein and nicotinic acid. The active component is a basic substance, possibly a pyridine compound. The deleterious effects of this extract are reversed by niacin or tryptophan. Although zein, the principal protein in corn, is lacking in tryptophan, corn itself has an appreciable quantity of this amino acid. Until the substance is isolated and its chemical structure established, it cannot truly be said whether or not it is an antimetabolite of nicotinic acid.

Poultry, cattle, sheep, horses, pigs, and rabbits fed large amounts of rye have poor appetites leading to lower growth rates. The cause of the reduced feed intake is due to an agent soluble in oil, acetone, and ether—a mixture of 5-N-alkyl resorcinols. Young animals are more susceptible to grain resorcinols than older ones. The decreased feed consumption of resorcinol-fed rats is not caused by any unappetizing taste of rye oil or rye resorcinols. There is no difference in harmfulness between fresh and 1 yr old rye.

Raw wheat germ is said to contain a chick growth inhibitor. The toxin is destroyed by heat or pressure cooking of meal. The primary effect of the toxin is to block the absorption of fat, although protein retention is also involved.

Many plants contain antibacterial substances, many of which are highly volatile. Their value may lie more in their use as preventives of infectious diseases rather than their use in therapeutics. Further studies may assign an importance to their use in prevention of bacterial and parasitic infections which affect nutritional values.

Cattle, calves and horses are susceptible to laxicity after eating substantial amounts of bracken fern. After about 30 days, horses show incoordination and an increase in rectal temperature and hemorrhages under the skin as well as some of the internal organs. Two toxic substances are present in bracken fern. One destroys thiamine and is responsible for symptoms seen in monogastric animals. Heating the dry bracken at 221°F for 18 hr

does not destroy completely the thiaminase factor. The active substances are destroyed by steam at 266°F for 30 min; they are dialyzable and thermostable in acid solution and can be extracted from aqueous solution with butyl alcohol. From the standpoint of poultry, it would seem reasonable to prevent the fern from being in green feed that is dehydrated.

A hypothesis accounts for most of the facts concerning antimetabolites. Essential metabolites such as the vitamins, hormones, and amino acids function by acting as substrates in enzymatic or semi-enzymatic reactions. For example, thiamine is known to act as substrate for the enzyme which synthesizes cocarboxylase (thiamine pyrophosphate). The antimetabolite exerts its effect because it, just like the metabolite, can combine with specific enzymes. Being a structural analogue of the metabolite, it has most of those chemical groupings which are responsible for the combination. However, the anti-metabolite is sufficiently different from the metabolite that the enzyme finds it impossible to form the usual product. The organism thus is deprived of a needed end product.

It cannot be assumed that a ration that is more than adequate in all nutrients will give maximum performance. Some natural feedstuffs contain phytate or oxalate which require higher levels of calcium and iron in the diet due to the fact that they form insoluble, indigestible precipitates with these elements. More of these minerals are necessary to supply the animal's needs in addition to that lost in the feces. Castor bean meal, even though a good source of amino acids, is not suitable in feed because of toxic factors.

Certain barley samples support better growth when enzyme supplements are added. Antibiotics in feeds may affect the intestinal bacterial activity and improve performance. More than adequate amounts of nutrients may contribute to nutrient imbalance. A low protein diet results in a reduced rate of growth; by supplementing this low protein ration with threonine, one of the deficient amino acids, a reduced rate of gain results rather than an increase which might have been expected. This effect is an amino acid imbalance.

INHIBITORS

As a result of trial and error, growth inhibitors or toxic substances in some plants and animal products have been recognized for sometime. *De Materia Medica* in the first century compiled over 600 plants of therapeutic or poisonous character. During the period of rapid western expansion in the United States, poultry and livestock came in contact with many new plants and many reports dealt with illness or death of animals due to sorghums, lupines, castor beans, and bitterweed, as well as "loco" poisoning.

Kingsbury recently compiled extensive information on the poisonous plants of the United States and Canada. Information is summarized on the accompanying chart (Table 21.1).

Cottonseed meal, Gossypol

One toxic component of cottonseed is gossypol, a yellow-colored substance which occurs in glands in all parts of the plant. The glands are oval-shaped and contain a semiliquid mass surrounded by a cellulose-like wall. Gossypol varies in color from yellow to orange to red to purple, and is synthesized in the roots of the cotton plant where it occurs at several times the concentration in seeds. In the glandless variety something prevents the transport of gossypol from the roots. Pigment glands can be separated from the meal by a flotation procedure using a mixture of organic liquids.

In commercial cottonseed meal, gossypol toxicity is reduced by the application of suitable heat and pressure. The released gossypol from the pigment glands combines with protein during heating to produce "bound" gossypol which is less toxic than the "free" compound. Binding of gossypol with protein involves the epsilon amino groups of lysine. Gossypol also reacts with glucose. Gossypol toxicity is reduced also by adding iron salts to rations containing cottonseed meal because this decreases the absorption of gossypol from the intestinal tract. Gossypol is 2,2′-bi-8-formul-1,6,7-trihydroxy-5-isopropyl-3-m-methylnaphthyl and was synthesized in 1958 by Adams and co-workers. Cottonseed meal contains also three pigments related to gossypol and derived from its heating. Very little is known concerning the biological significance of these pigments.

The animals most sensitive to gossypol toxicity are guinea pigs, rabbits, swine, and dogs; rats and poultry are less sensitive. Mature ruminants are immune to gossypol, possibly because gossypol combines with soluble protein. Calves are susceptible to gossypol before the rumen flora is established.

Symptoms of gossypol toxicity are depressed growth rate and decreased utilization of feed. The younger the animal, the more susceptible it is. Animals continue to eat almost until they die. There is congestion and edema of the lung, liver, spleen, and lymph nodes, and a flabby, dilated heart. Livers show intralobular necrosis. Seriously poisoned birds show dyspnea, with labored, audible respiration. Chicks develop leg weakness, edema and enlarged gall bladders, emaciation, anemia and serous fluid in the pericardium and peritoneum. There is a reduction in feed intake and a cessation of egg production.

Hens fed cottonseed meal produce eggs that develop discolored yolks and whites during cold storage. Two groups of compounds are involved.

TABLE 21.1

PLANTS WHICH MAY CAUSE TOXIC REACTIONS WHEN INGESTED BY ANIMALS

Alkaloids	Cyanogenetic	Goitrogenic	*Irritant* Oils	Cardiac Glycosides	*Saponins*	Oxalates
belladonna	catclaw	chard	horseradish	pheasants-eye	corn cockle	beet
jimson weed	bahia	kohlrabi	wh. mustard	dogbane	tung tree	halogeton
henbane	mt mahogany	wh. mustard	Indian mustard	Lily-of-the-valley	beech	sorrel
Crotalaria	florestine	*rape seed*	wormseed must.	foxglove	English ivy	purslane
viper's bugloss	mannagrass	*bl. mustard*	charlock	*oleander*	yellow pine	Russian thistle
heliotrope	velvet grass	kale	wild radish	*be-still tree*	*alfalfa*	*greasewood*
groundsel	hydrangea	broccoli	baneberry	squill	bounc. bet.	alocasia
hemlock	birdsfoot	cabbage	windflower		coffeeweed	J-in-the pulpit
Indian tobacco	trefoil	Brussels sprouts	marigold			caladium
tobacco	cassava	rutabaga	buttercups			wild calla
prickly poppy	lima beans	Chinese cabbage				eleph. ear
celandine poppy	cherries	*turnip root*				dumbcane
fitweed	apple	soybean				philodendron
Dutch breeches	Sudan grass	flax				skunk cabbage
poppy	queen's delight					
bloodroot	poison suckleya					
ergot	*white clover*					
jessamine	arrowgrass					
manchineel	vetch seed					
African rue	corn					
false indigo						
Scotch broom						
goldenchain						
lupine						
mescalbean						
tomato						
potato						
staggergrass						
false hellebore						
death camas						
monkshood						
larkspur						

TABLE 21.1 (*Continued*)

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Resinoid	Phytotoxins	*High nitrates*			High Selenium	Photosensitization
milkweeds	prec. bean	pigweeds	cheeseweed	var. thistle	*poison vetch*	buckwheat
marihuana	tung tree	bishop's weed	sweet clover	nightshades	prin. plume	St. Johnswort
water hemlock	barbadosnut	tarweed	*miner's lettuce*	goldenrods	goldenweed	lechuguille
laurel	castor bean	bluegreen	witchgrass	sow thistles	woody aster	cult. rape
Labrador tea	black locust	algae	johnsongrass	horsebean	aster	lantana
chinaberry tree		beggar tick	horsebean	chickweed	saltbushes	sacahuiste
rustyleaf		rescue grass	popcorn flower	mustard	paint brushes	panic-grasses
Japanese pieris		*plumeless*	smartweeds	punct. vine	bat. roadflax	horsebrush
laurel, rhododendron		thistle	Calif. chicory	nettle	gumweeds	punct. vine
		pigweed	dock	crownbeard	hop-sage	water bloom
		lamb's quarters	Russian thistle	celery	*snakeweed*	oats
		Canadian thistle	annual sage	cucumber	tansy aster	milk purslane
		Rocky Mt. bee	elder	squash	beard tongue	molds
		poison hemlock	flax	carrot	ironweed	alfalfa
		bindweed	alfalfa	soybean		smartweeds
		jimson weed	radish	*barley*		summer cypress
		barnyard grass	rye	sw. pot. vines		Sudan grass
		goose grass		lettuce		clovers
		joe-pye weed		Sudan grass		vetches
		thoroughwort		wheat		anemone
		milk purslane		*corn*		poverty grass
		wh. ragweed				turkey mullein
		purple cudweed				squir. barley
		coast goldenbush				pea straw hay
		wild sunflower				blackberry vines
		fireball				foxtail grass
		prickly lettuce				needle grasses
		skeletonweed				crimson clover

Cyclopropene fatty acids impart a pink color to egg white and yolks; gossypol darkens the color of the yolk. The pigmentation of the egg content is not evident when the eggs are laid but appears after about four weeks storage.

The cause of the discoloration of the egg content is due to an increased permeability of the vitelline membrane which surrounds the yolk. This is caused by malevolic and sterculic acids which are in cottonseed oil in the ratio of 2:1. The relaxed membrane causes a gradual increase in the pH of the yolk approaching that of the white. In the yolk an increase in water content and a decrease in ammonia, iron, and fat occur.

The pink color in the egg white results from iron diffusing from the yolk and reacting with conalbumin, a protein fraction of the white, to produce a complex with a characteristic pink color. It is possible to determine if eggs are from hens fed cottonseed meal by exposing the fresh eggs to ammonia. This brings out immediately the gossypol discoloration of the yolk.

Soybeans

Soybeans are of less nutritional value when raw than properly heated. Mice are more sensitive to raw beans than chicks and rats. The age of the animals influences sensitivity to the toxic factor. For the first 8 to 12 weeks of life, chicks show a growth depression on a raw soybean ration but eventually they gain in weight at a rate equal to those fed heated beans.

There is some controversy as to whether hens do equally well fed heated and raw soybeans. Eggs from hens fed raw soybeans are as fertile and of the same yolk quality as those produced by hens fed heated soybeans. But they contain several times as many blood spots as the control eggs.

In processing soybeans, dry heat is not as effective as autoclaving for 15 to 20 min at temperatures ranging from 212° to 248°F. Maximum improvement in protein efficiency ratio (PER) occurs when beans are pressure cooked. Raw soybeans in the ration cause the pancreas to enlarge severalfold and reduce fat absorption.

The inhibitory substances in raw soybeans depress the utilization of methionine and cystine. Methionine and cystine or both added to a raw soybean ration increase the growth rate of chicks. The decreased availability of methionine in raw beans is due to the slow rate at which it is released in the gut. Methionine does not completely compensate for the growth differential between raw and heated soybeans, nor does it prevent the increase in the size of the pancreas. The addition of other amino acids does not improve performance of raw soybeans.

Raw soybeans and navy beans contain a trypsin inhibitor which explains why heat treatment improves nutritional value. Animals fed raw soybeans excrete a higher percentage of ingested nitrogen and sulfur in

their feces than animals fed heated soybean rations. Some factor other than the trypsin inhibitor is responsible for the different values of raw and heated beans because, if so, the difficulty should be overcome when amino acids are used in the ration instead of the intact protein. However, this does not occur. Such studies rule out the possibility that raw soybeans owe their poor biological value to an interference with intestinal digestion of protein. As previously stated, chicks fed raw soybeans have enlarged pancreases. This suggests a compensatory mechanism for the reduced tryptic activity. Since there is no change in the concentration of proteolytic enzymes in the pancreases of birds fed raw soybeans because of their larger size, the total activity is increased.

Raw soybeans also have hemagglutinins which it is claimed may be partly responsible for the growth depression in animals fed raw soybeans. Since the activity of hemagglutinins is readily inactivated by pepsin, this fraction should be completely inactivated before the beans enter the intestine. The addition of antibiotics to a ration containing raw soybeans also enhances its biological value. Antibiotics may not act entirely by altering gastrointestinal flora but may inhibit excessive pancreatic secretion.

Raw soybeans and a number of plant products reduce the availability of such trace minerals as zinc. This effect has been ascribed to phytic acid in the case of soybeans.

Linseed Meal

Chicks fed linseed meal grow at a slower rate than normal. The growth-inhibiting substances in linseed meal are destroyed by autoclaving or by incubation with water or 50% ethyl alcohol. Drying(230°F) has no effect. The addition of pyridoxine hydrochloride to rations containing linseed meal increases weight gains even though the ration initially contains an adequate amount of this vitamin. The highest concentration of the growth-inhibiting substance occurs in meal with the cotyledons containing the most of the substance. There is practically none in the hulls isolated from flaxseed. A crystalline substance isolated from unheated linseed meal is soluble in water but insoluble in organic solvents and contains 50% glutamic acid.

Raw Fish

Certain species of raw fish in the diet of certain animals interfere with the absorption of iron and destroys the thiamine in the ration. Raw coalfish, whiting, hake, carp, and some other fish, from both fresh water and salt water, contain the substance. Mink become anemic and develop light colored underfur; mortality is high. Boiling the fish prior to its incorporation in the ration overcomes the difficulty.

One factor is the enzyme, thiaminase, which is more concentrated in the viscera since eviscerated fish are not as toxic as the whole fish. Supplements of thiamine or cooking the fish overcomes the effect of the thiaminase, or raw and cooked fish can be fed on alternate days.

Cycad

Cycad is a palm-like tropical tree that produces seeds in aggregates on the female plant. Natives on the island of Guam use the kernel for food and the outer hull of the seed as a confection. Humans and animals consuming cycad develop progressively incurable paralysis of the extremities. Etiology and effective treatment of the disease are not known. Natives recognize that the kernels are toxic and attempt to eliminate the toxic substances by soaking the kernels in water for 7 to 10 days. After drying, the powdered material compares closely with wheat flour in appearance, chemical composition, and use. The toxic substance (methylazoxymethanol) is cycasin, a glucoside which makes up 2% of the unwashed dried kernel.

Chicks, rats, guinea pigs, horses, cattle, and swine fed cycad develop severe centrolobular necrosis of the liver. In rats, hepatomas develop which metastasize to the kidneys, lungs, pancreas, and intestinal tract. Both the hull and kernel of the seed are toxic.

Alfalfa Meal

Levels of alfalfa meal in rations in excess of 5% inhibit the growth of chicks. Inhibitors can be removed by exhaustive extractions of the meal with hot water. The inhibitor(s) are soluble in 50 to 80% ethanol; acetone precipitates it from an aqueous alcohol solution. The agent is saponin which depresses growth, feed consumption and feed efficiency, as well as egg production. Saponins from alfalfa have hemolytic activity. The inhibitor is labile in water so that its activity disappears from alfalfa extracts while they still contain saponins. Cholesterol counteracts the effects of the inhibitor.

In addition to alfalfa, Ladino clover and black medic contain saponins as well as an enzyme, pectin methylesterase (PME), which is responsible for cattle bloating. It reacts with pectin of forages, changing it to pectic acid and alcohol. The former reacts with calcium in the rumen and produces a sticky substance which traps gases formed in digestion. As the gas accumulates and the rumen swells, the animals become bloated. Alfalfa hay contains about four times as much PME as grass. The problem occurs more frequently in fields after a frost in the fall.

The estrogenic compound, coumestrol, the related coumestan, trifoliol; the estrogenic isoflavones, genistein, diadzein, biochanin A, and formonetin; the dicoumaryl ether, daphnoretin; and the flavone, tricin have been isolated and identified in alfalfa.

ANTAGONISTS

Vitamin B_6 Antagonists

When desoxypyridoxine is fed in the diet, skin lesions and other characteristic signs of vitamin B_6 deficiency develop. When vitamin B_6 is incorporated in normal amounts in the diet, the antagonistic action of desoxypyridoxine is prevented. One interesting difference, however, is noted. When vitamin B_6 deficiency is induced by feeding desoxypyridoxine, *there is no reduction in the vitamin B_6 content of the liver and other organs* as usually occurs when a deficiency is induced by a vitamin B_6 diet. In fact, the amount of pyridoxal phosphate remains high in the tissues, and the activity in the trans-aminases in liver and heart and glutamic-decarboxylase in the brain remain essentially unchanged unless the deficiency is extreme.

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Feed Ingredient Quality

PART 1 Quality Control

INTRODUCTION

Quality control is a state of mind, an attitude that begins in product development, continues with the purchase of raw material, follows through the manufacturing process, distribution, and storage, and ends in successful field performance. Feed quality control is a mandate to be certain that manufactured feeds are capable of performing properly. Excellence cannot be expected from a feeding program unless all significant components have been subjected to advanced scrutiny and checking. Vigilance, experience, judgment, and organizational setup should be geared to achieve objectives in the soundest manner.

Ingredient suppliers constitute the first bulwark of defense by counseling the buyer. In the feed mill, test work is usually done best on the "pick and choose" basis. Establishing a working range for any given factor in the feed is the essence of quality control which more than any other single factor is the one that bridges the gap between technology and successful use of manufactured feeds.

At one time, "feed was feed" just as long as it contained the same percentage of protein, fat, fiber, and minerals. Science, however, has shown that this is not enough. A ton of one feed is not equal to a ton of another having the same chemical analysis; one may be worth twice as much as another. This difference in feeding value is commonly referred to as "quality." The basis of quality formula feeds is the quality of the ingredients. It is the kind and quality of the individual ingredients that are used which determine the value of the finished feeds. This is illustrated by citing an example. As previously stated, protein varies in quality depending on the number and percentage of its specific amino acids. But amino acids makeup of proteins is only one factor which affect their value. The digestibility of protein is also important. A feed in which 85% of the protein is digestible is of higher quality and greater value than one in which only 75% is digestible. Thus, low feeding value or quality can be due to poor amino acid makeup or poor digestibility.

Temperature of processing in the manufacture of a product affects quality. Low temperatures are conducive to the production of higher

quality products than those produced at a higher temperature. The temperature is destructive in certain instances, yet is beneficial in processing soybeans which have to be subjected to heat treatment to give a mild roasted and nut-like flavor and improve feeding value. The mineral content of a feedstuff also influences quality. The superior value of legumes is due not only to their higher protein and vitamin contents but also to a larger amount of calcium. Quality is also a factor with vitamins. The value of alfalfa meal cannot be judged entirely on the basis of its protein and fiber contents or color. These are of value but can be misleading. Alfalfa meal may be high in protein and low in fiber, yet contain only 50% as much riboflavin as another meal of similar chemical analysis. It may be of good color, yet low in carotene.

Quality feeds mean a quality program from the beginning to the end. Many farm poultrymen are not qualified to judge the results of a good feed. A poultryman might use inferior mash and get good results temporarily. He should be shown that the feed cost per dozen of eggs will be definitely lower when a good feed is used. Because few farm poultrymen keep adequate feed records, it may be difficult to demonstrate that more of the inferior mash will be required than a good feed.

Quality in feeds applies also to grains. Federal grades for grains have quality as their chief criterion. Grains, for example, vary in chemical analyses due to the climate, soil, fertilization, rates of growth, and variety. Grain by-products vary due to the source of the raw materials, processing methods, and storage conditions. Grains below standard in weight, moldy, or off-grade are not as good as those which contain sound grains of a good grade.

THE NEED FOR SEVERAL GRADES OF FEEDS

It would be simple if a feed manufacturer could market 1 quality of feed and keep all his customers satisfied but surveys of the industry show that feedmen can only hope to sell about 70% of feed buyers. Ten percent at the top of the list wish to buy the most expensive feed. They believe that there is only one "best" feed and price is no object. Of course, there is no such thing as a "best" feed. Several such high quality feeds are possible and produce superior results depending on the conditions under which they are used. At the other extreme, there are 10 to 30% of the customers who look at feed from the standpoint of price. They want the lowest price. Thus, the feed manufacturer in a specific community must adapt to the consumers in that area. One feed will not satisfy all customers. As a result, feed manufacturers make more than one grade of feed. His first grade of feed fits the quality ideals of the majority of the people in the community he serves. He also manufactures a 2nd grade where price

enters into consideration more extensively, and perhaps, a 3rd grade of feed, based on price only.

The feed manufacturer must temper nutritional requirements with other attributes such as the appearance, texture, odor, taste, and physiological action of his feed. His first grade of feed is good enough so that it will be complete for chickens fed under the most adverse conditions. The second grade of feed is usually correct from a nutritional standpoint, but contains substitutes of high grade feedstuffs. Cheaper fishmeals and meat scraps are used instead of the higher quality steam or vacuum dried products. The third grade of feed is practically always competitively priced. Nutritional ideals are ignored and feeds are put together from the standpoint of meeting necessary legal guarantees only and are not worth their cost. Sales arguments sometimes explain feeds on the basis of protein quality, vitamin quality or minerals, in spite of the fact that a deficiency in any one nutrient interferes with the utilization of the complete feed.

NUTRITIVE VALUE AND QUALITY

Nutritionists know that the nutritive properties of individual feeds are not additive when combined into rations because of the associative effects on digestion and their supplementary effects on metabolism. There is more to nutrition than the mere combining of known compounds into a feed and the calculation of the costs of these constituents. The final test of a feed is to feed it. Chick feed should be tested with chicks, and laying feeds with layers.

The quality of mixed feeds is determined by the aim and purpose of the feed manufacturer who must gear his feeds to the merchandising program and the consumer. The quality of ingredients used in mixing feed is of utmost importance. This can be illustrated with a concrete example: give the same feed formula to two different feed mixers. One may use top quality grains, mill feeds, meat, fish and soybean meal, milk products, and alfalfa meal. If he does an accurate mixing job, he turns out first class feed. Contrast this to a mixer who is not quality minded. He can take the same formula, use low quality and possibly damaged grain, mill feeds and out-of-condition products that were bought because they were cheap, vitamin oils of uncertain potency, alfalfa poor in quality and color, cheap milk bought because it was scorched, and he turns out a feed that possesses nowhere near the feeding value or quality of the first feed mixer.

MIXING QUALITY FEEDS

The feed mixing operation may also affect the ultimate quality of feeds. In continuous mixers, the ingredients are proportioned by means of proportioners or feeders at the bottom of the bins. Most feeders work accord-

ing to volume instead of weight. If feed ingredients vary in their weight per bushel, a wrong proportion occurs in the final feed. Materials such as middlings, alfalfa meal, and dried milk vary in weight per bushel from one lot to the next, so the weight per bushel of each carload of ingredients must be checked. Also, mechanical details in connection with batch mixers may cause poor quality. In most equipment there are places where some of the feed materials can lodge. The boot of the elevator in a batch mixer has considerable space in it which is filled up with feed. In screw-type equipment, there is a small amount of space at the bottom where the feed can collect. In the scraper type, the fit of the scraper allows some feed to remain at some point in the housing. This fact makes it important to be careful how the ingredients are put into the batch mixer.

The word "substitute" may be construed to mean that one ingredient fully takes the place of another in all respects or it might mean that it is the next thing to use when the preferred one is not to be had. For example, in any replacement of soybean meal for fishmeal, there are other considerations besides protein. Watch all aspects before making substitutions.

The feed manufacturer should realize that he is doing the feed industry great harm by selling poor feeds cheap. All phases of the feed manufacturing must be subjected to an evaluation of quality. The feed man is concerned with chemical content, weight, densities, textures, particle size, chemical properties, and many other numerous characteristics of the ingredients handled. His task is to blend by uniform and controllable methods these raw materials into a nutritionally sound product. The feed must be consistent and have a quality which he can honestly represent to the farmer as capable of efficiently producing poultry.

THE IMPORTANCE OF PROPER SAMPLING

Quality control should not be looked upon as something which must be done because of governmental regulation but rather as an obligation to the growth and continued successes of feeders and the feed industry. To determine quality at various points in the manufacture of feeds, representative samples of the material are taken to be evaluated. Bulk material is best sampled with a standard 63-in. double tube grain tool which has 10 openings. The probe is inserted at angles of about 10° from the vertical; the slots should be up when the probe is open. Twisting the probe permits filling of the tube. When the probe is withdrawn the contents are emptied into a sample container. Bulk meal in cars require 10 to 25 probes taken from different sections of the car. For bulk meal in trucks, 5 to 8 probes are taken at uniformly spaced points of the truck. For sacked materials, 2 to 4-oz probes are withdrawn from 5% of the number of sacks. When sampling of finished or mixed feeds is desired, one 4-oz sample for each

1,000 lb of feed in a continuous operation or a 5-oz sample for each 1,000 lb under batch mixing conditions should be taken. When sampling is completed, mix and divide into 2 equal parts—1 for analysis and 1 to be held for record control.

Observations are made on the size, color, appearance, odor and texture, using a hand lens or microscope to yield information as to the wholesomeness of the material, the presence of foreign material, and the extent of particle or grain damage. A moisture analysis may be run to indicate the relative percentage of pure material in the sample. Chemical analysis on spot samples for Amprolium, riboflavin and ash contents are used to determine mixing efficiency.

Use of Averages and Standard Deviation

When discussing quality of feed ingredients, one normally uses averages of a number of values. The standard deviation of the mean can then be calculated. This is very useful for it indicates that 68.3% of all future determinations of similar material could be expected to fall within the range of the average value plus or minus 1 standard deviation. Similarly 95.5% of all future determinations would be expected to fall within the average value plus or minus 2 standard deviations. The mean or average and standard deviation, therefore, give a method of comparing incoming loads of ingredients of the same type analyzed for the same quality characteristic.

To compensate for ingredient variations, several alternatives are available if close attention is paid to the source of manufacture and supply, and to the actual guarantee or laboratory analysis of the ingredients purchased, rather than to the average composition given in standard charts. It is possible to reduce variaton by blending many loads of a single ingredient in a large storage facility or by depending on the natural mixing during output of flow to compensate for the actual variation. Also, by sampling all shipments prior to unloading, it is possible to segregate loads into above-average and below-average bins.

Moisture Content

Nutritionists select ingredients that supply energy, protein, vitamins, and minerals at the desired levels for poultry. A primary factor which will affect the energy content of a grain will be the moisture content. The moisture content for corn, for example, can easily vary 3 percentage units, e.g., from 13 to 16%. This differential in moisture content amounts to 50 to 60 Cal in a ton of finished feed. This could result in a change of 4% in the efficiency of production, and ½ cent in the cost for a dozen eggs.

Protein Content

A fallacy of protein evaluation is that chemical analysis is made for nitrogen content; a factor of 6.25 is multiplied times the nitrogen content

to obtain the value of protein. But not all nitrogen in feed ingredients is utilizable protein or available amino acids. Some is present as nonprotein nitrogen and very little of this can be used as a substitute for protein. Products such as shark meal and blood meal contain high levels of nonprotein nitrogen and are thus overestimated for protein quality.

The ability of nutritionists and computers to formulate good rations is limited primarily by the precision of the analytical data on the ingredients used. Every effort should be made to provide maximum control measures in production. Quality control is a service to customers rather than a legal requirement. Application of existing data, methods, and materials should go a long way to implement sound control procedures. It is necessary to pay particular attention to the utilizable energy in feed ingredients and to protein quality. Seventeen percent alfalfa meal may contain more than 100,000 IU of vitamin A activity per pound or no vitamin A activity. Solvent-extracted soybean meal may be properly heat treated and an excellent source of high quality protein or inadequately heat treated with much less feeding value. Cottonseed meals have widely varying gossypol contents which affect feeding value. Poor quality feed is likely to interfere with growth and feed conversion rather than kill animals or even make them obviously ill.

A method of control especially useful to the small feed manufacturer is buying ingredients from specific plants of companies which are well-known for uniformity and quality. Some ingredient companies try to make certain their products are as uniform as possible. Feed manufacturers rely to a considerable extent on tables of average analysis of ingredients in order to calculate the proximate analysis of a feed. The value of these tables is greatly reduced unless actual chemical assays of incoming ingredients show a range of results close to the figures in the table. A lack of citations from state laboratories for deficiencies in samples of feedstuffs picked up by inspectors provides only a minimum insurance that tag guarantees are being met.

Coccidiostats Important

Another quality problem involved a drug to control *coccidiosis*. Nicarbazin, a good coccidiostat, worked well with broilers. Hens consuming it for any length of time, however, lay soft-shelled or no-shelled eggs.

PIGMENTATION OF BROILERS AND EGG YOLKS

In finishing feeds, one of the problems is pigmentation of broilers and egg yolks. In one part of the country they like birds to be white; in another part they prefer yellow birds and yellow egg yolks. People will not eat eggs with pale yolks in some parts of the country because they think they come from sick chickens; in other locations they want pale eggs and will

not eat eggs with dark yellow yolks. Egg breakers want eggs with a deep yellow yolk to help color cake mixes. All of this can be accomplished by proper feeding. It is a matter of knowing what the market wants and adjusting feed formulation. Of interest to poultry people at the present time is seasonal formulation. Rations for laying hens are formulated geographically, depending on the part of the country they are being sold in and the season of the year.

In the manufacture of formula feeds, some ingredients are present in small amounts and are measured very accurately and permit no deviation. In this category may be listed medications. Every effort must be made to have no overage or underage. Approval for medicating feeds must be given by the Food and Drug Administration who also require that analytical methods be available for drugs. Some drug suppliers provide a laboratory service with respect to their own drugs on a more or less limited basis to users of their products to provide information on mixing efficiency.

ANALYTICAL METHODS

Chromatography as an Analytical Tool

Many sophisticated procedures and equipments are available now for assay of ingredients. A technique that has advanced biochemistry more than any other in recent years is chromatography. This involves the separation of a mixture of materials into individual components by passing a solution of the mixture over an absorbing material, such as powdered clay, blotting paper, or sugar. Types of chromatography are thin-layer, paper, column, and gas. In paper chromatography a strip of porous paper with a spot of the mixture near one end is suspended in such a way that liquid either descends down the strip by siphoning from a reservoir or ascends from the bottom by capillary action. Thin layer chromatography is similar to paper chromatography, except that a slurry of the absorbing powder is spread on a glass plate and dried to produce a thin sheet. This sheet of powder supported on a glass plate is then treated as if it were a sheet of paper. In column chromatography a glass tube is packed with an absorbing powder, a mixture added on the top of this column of powder and solvent allowed to run down through the column. Gas chromatography is similar to column chromatography, except that a stream of gas is used to move the components of the mixture through the column. This is done at high temperature so that the mixture boils and is moved as vapor.

In the paper thin-layer method, the individual components are located by removing the solvent reservoir, drying the sheet and spraying with a dye which colors the various materials. By comparing the distances moved with pure chemicals, unknown materials may be identified. In column or gas

methods, various detection devices are placed at the end of the column to monitor the materials coming out. Alternately, the gas and liquid coming out of the bottom may be collected in small amounts and each fraction analyzed to determine whether a component is present, and if so, what it is.

Other Laboratory Instruments

Colorimetry is also used to a great degree. This compares and measures colored solutions. Referring again to carotene and vitamin A, the former forms a yellow-colored solution when dissolved in a suitable solvent, which is easily measured. Antimony trichloride in chloroform reacts with vitamin A to produce a deep blue-colored solution, the intensity of which is proportional to the vitamin A present. Practically all tests for drugs and feeds are based on colorimetry. Accurate photoelectric colorimeters are available for this work. Other laboratory instruments are spectrophotometers and flame photometers. The operating principle of the latter is based on the fact that many elements such as calcium, sodium, and potassium impart a color to a flame. The intensity of the color is proportional to the amount of element present. Trace minerals are analyzed by this method.

This discussion indicates how expensive a feed quality control program could be if all the nutritional aspects of a feed were examined. No feed manufacturer has the facilities and personnel to check all the nutrients in their feed regularly. However, control of certain common components of feed, at least those guaranteed on the feed analysis tag is certainly a good investment.

With the advent of more complex feed mixtures, it has become imperative on the part of feed manufacturers to police their operations. Today, instead of pounds per ton we think in terms of grams and micrograms for certain critical nutrients in building a modern feed formula. When we speak of quality in reference to feed, we are speaking of the highest type rather than the lowest type of quality, in other words the best feed that it is possible to produce. Control of quality is a most important function and without policing, the quality of mixed feeds could not be maintained. The purpose of quality control is to produce products which are uniform and have the ability to give economical and outstanding results. Quality control sets up purchasing specifications to guide the purchasing department, samples carload shipments, checks the physical condition of the material, observes possible heating, insect infestation, foreign odors, foreign materials, and other physical conditions which affect quality.

Tests of Products in Storage

Laboratory control protects the quality of feed ingredients while in storage. One method is to measure temperature changes in storage bins. Re-

cordings of bin temperatures indicate any heating of a commodity. If so, the material is put into immediate use or turned to cool it before deterioration takes place. Quality control checks cover processing equipment including grinding, pelleting, cracking, crimping, and various other milling operations. Checks should be made that each proportional feeder delivers the proper amount of each ingredient called for in the formula. Quality control operates independently of the production department. Quality control personnel must see that there is no irregularity to cause mechanical breakdown or "hanging up" of ingredients in the bin. Quality control is a 24-hr per day operation and QC personnel must work closely with the production department. This preventive type of control on the spot at the time of mixing insures quality in the finished feeds. Once a feed formulation is made, it is almost impossible to doctor it up if it is not correct.

Thus, quality control of mixed feed is the result of the combined effort of many individuals working in close cooperation. Quality control has complete power in accepting or rejecting purchases made by the purchasing department. Their function is constant patrolling to produce as uniform a product as possible and to minimize variations caused by raw materials, processing equipment and human error.

How is the quality of the ingredients that make up a formula determined? Appearance, physical characteristics, chemical analysis, microbiological analysis, and animal feeding tests may be evaluated. A good example of this is corn cockle contamination. This little seed, about the size of a pinhead, gets into corn. If these seeds are present in grain in any great quantities, chickens become ill. Some physical limits must be established on how many can be in a pound. If the grain does not meet the standards, it should be refused.

Alfalfa is a good ingredient for pigmentation. The fiber is high which is a problem in making pellets; if there is too much fiber, the pellets fall apart. Customers are unhappy because they paid for pellets and received meal. The chemical analysis maintains standards set for ingredients.

Microbiological Methods

Chief problems are Salmonella and aflatoxin. Salmonella are found most commonly in meat by-products, meat meal and fishmeal. Aflatoxins are found in peanut meal and cottonseed meal; every effort is made to keep them out.

Animal Feeding Tests

These tests are conducted to obtain information on how animals will perform, establishing standards, and evaluating ingredients. A number of years ago, animal fats were blended with certain fat-like residues. The

product had a certain amount of energy and when added to feed for rats, they did not appear to be affected. One could not detect the product by any of the standards at that time. When this was fed to broilers, they developed a condition called "water belly." Millions of birds died and several feed companies lost millions of dollars. The tests had not been complete enough. The rats had not shown any ill effects, but the feed manufacturers did not check it on chickens.

TYPICAL QUALITY CONTROL PROGRAM

It is routine procedure to incorporate a host of the B-vitamins, vitamins A, D, E, and K, unidentified growth factors, antibiotics, coccidiostats, bactericides, arsenicals, hormones, and antioxidants in the modern feed formula. The tolerances of some of these components are narrow. Specific drugs are designed for specific feeds. Thus, the modern feed formula must be precisely manufactured. A detailed program should be developed by the respective manufacturing unit depending on the local factors involved.

A quality control program can be divided into three phases: (1) quality control of incoming ingredients; (2) quality control on production; and (3) quality control on finished products.

Quality Control of Incoming Ingredients

Quality feeds cannot be made from inferior ingredients. (1) Use AFMA Buying Guides and buy on grade and specification from reliable suppliers, and periodically check on the maintenance of the quality. (2) Physically check for the following characteristics: color, odor, texture, moisture, temperature, and uniformity and bulk density on certain items. (3) Microscopically examine for contaminants. (4) Chemically analyze ingredients using A.O.A.C. methods wherever possible as follows:

Grains—protein, fat, fiber, moisture
Mill feeds—protein, fat, fiber, moisture, ash
Soybean oil meal—protein, fat, fiber, moisture, urease activity, water, soluble N
Cottonseed oil meal—protein, fat, fiber, free gossypol, nitrogen solubility, moisture
Other vegetable proteins—protein, fat, fiber, moisture
Animal proteins—protein, fat, moisture, ash, NaCl, pepsin, digestibility acid insoluble ash, nonprotein nitrogen, protein quality index (Almquist)
Urea—protein
Animal fat—A.O.M., moisture

Alfalfa meals —protein, fat, fiber, moisture, carotene
Molasses—moisture, sugars, degrees Baumé or brix
Minerals—specific mineral
Trace minerals—specific trace mineral
Vitamins—specific vitamin
Hormones—specific hormone
Drugs—specific drug

(5) Biological analyses periodically of key ingredients. (6) Microbiological analysis for vitamin and antibiotic determinations.

It is obvious that the expense of assaying every shipment of every ingredient for all of the above factors would be prohibitive. These procedures described above are to be used at the discretion of the individual responsible for the quality control program.

Quality Control of Actual Production

Quality control is so important that adequate authority should be given to responsible personnel to assure the success of the program.

The personnel involved in quality control should: (1) be thoroughly familiar with the feed manufacturing equipment involved in order to know its advantages and its limitations; (2) develop checkoff and inventory procedures applicable for the manufacturer of vitamin, antibiotic, hormone, drug, and mineral premixes; (3) develop whatever checkoff systems are needed for the actual feed manufacturing operation; (4) establish definite systematic sampling procedures which will assure obtaining truly representative samples; (5) utilize appropriate chemical tests to determine the thoroughness of mix in premixes and formula feeds (To determine the uniformity of mixing, individual samples taken through the batch should not be mixed, but should be assayed separately.); (6) routinely check incoming shipments and holding bins for insect and rodent contamination; and (7) develop an educational program to acquaint production personnel with the importance of the quality control program.

Quality Control on Finished Product

The finished product should be checked for correctness and uniformity of mix by the following physical and chemical tests: color, odor, texture, moisture, protein, fat, fiber, ash—specific minerals, specific trace minerals, specific antibiotics, specific vitamins, specific drugs, and microscopic examination.

Biological (actual feeding) tests of the various finished feed formulas are recommended. Periodic feeding tests will not only serve as a check on the quality of feed, but will also verify to the feed manufacturer the type product he is producing.

Quality control, like the feed industry itself, is dynamic and ever-changing. Intelligent application of the principles outlined above will assure the feed industry that every pound of manufactured feed will do the job for which it is designed.

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PART 2 Feed Palatability and Appetite

APPETITE

What is the signal that stimulates the animal to eat? It was formerly thought to be due to lowering of the blood sugar which causes an urgency for more food. However, there are specific centers in the hypothalamus of the brain which control feed intake. This is a portion of the brain stem and two different parts are involved. This was learned by surgically damaging certain areas and observing how it affects the animal. Damaging a certain part of the hypothalamus increases food intake or causes hyperphagia. Damage another part of the animal and it completely refuses food; this is called aphagia. Rats become exceedingly fat because of damage to this gland. Thus, it is possible to stimulate these centers and increase or decrease food intake. Three major theories with respect to the regulation of food intake are consistent with the known functions of this gland. In the glucostatic theory, it is believed that appetite and satiety are related to the level of the blood sugars; in the thermostatic theory, it is a matter controlled by temperature; in the lyphostatic theory, it is a matter controlled by fat stores of the body. There are strong points and shortcomings for each of these theories.

PALATABILITY OF FEEDS

Along with appetite, there is the matter of taste and palatability of feeds. Each species has a characteristic natural diet and exhibits food preferences for these ingredients. Practically all domestic animals have taste buds but live in a different taste world than humans. The interest in flavor for poultry feeds stems largely in the hope that feed intake might be made to increase. If there is a flavor that is attractive to the animals, more feed will be consumed and faster and more efficient growth will result. It has not worked out as well as one might suspect. Formerly, feeds were frequently flavored. Perhaps the feedmen liked the odor and flavor, and assumed that chickens would like it also.

Palatability of the feed is not an index of nutritional value. Birds eat more of a less palatable mixture than one that seems more palatable. Birds have a sense of taste and incidentally live in a world of color. Palatability is a complex, poorly understood subject. Although the feed companies have studied this subject in some depth, they have found little which can be applied practically. For instance, saccharin tastes sweet to us but is not relished by poultry; however, calves like it. Moderately high levels of salt in the feed is offensive to some birds; not to others. Chickens like fresh rather than stale feed. Staleness may be a matter of residues of rancid or oxidized fat which chickens do not like.

If the maximum use is to be obtained from feed, freshly prepared feeds

should be fed. An experiment conducted in the Southeast with turkeys emphasizes this point. The same feed formula was used. In one case, fishmeal stored for ten months was used; in another the fishmeal was produced fresh. Many poults refused to eat the ration when it contained as low as 4% of stored fishmeal. Interestingly enough, the stored fishmeal was extracted with a solvent and the fat and meal both were detrimental.

Consumption

In controlled experiments carried out over many years, there was no flavor or taste that made birds consume more feed. A temporary increase might occur but soon the birds got back to their original consumption levels. Birds taste via taste buds and seem indifferent to common sugars that people would call sweet. Since the chicken is capable of color perception, this influences selection to some extent. A number of spices were added by the author to feed of broilers hoping that they would affect the flavor of the meat and thus consumption. Feed intake was the same and the only spice that affected flavor of the meat was garlic and this flavor effect might have come by way of the lungs rather than from ingestion. A taste panel recognized it and did not like it.

The Research Director of a large feed company who has tested flavors by the thousands reported that he found no odor or flavor that would continuously keep the intake of the birds above normal. Yet, there are many flavor companies marketing specific flavorings for poultry, claiming that flavors overcome palatability problems during periods of changeover of feeds. They mask unpalatable additives in the feed, for example, mineral supplements where there is a matter of texture to overcome. Water-soluble minerals also produce an alkaline taste strongly rejected by animals. It is claimed that animal feed flavor makes such minerals better smelling and eliminates the alkaline taste. Most animals, except poultry, have a liking for sweet types of foods.

If carbohydrate in the feed molds, it produces materials which are distasteful to animals. Flavoring might offset this but the proper thing to do is to prevent mold growth. One of the first ingredients used to flavor feed was molasses. It is claimed molasses masks poor quality ingredients and makes them satisfactory for animals.

Avian taste buds were first described in 1904. They are in the highly cornified, anterior part of the tongue and composed of three types of cells. The acuity of taste in the fowl is related to the number of these sensory cells. Adult chickens have only half the number of very young birds and thus are less sensitive to taste than younger birds. There are many instances where some species of animals differ from others in taste. Chickens, quail, jungle fowl, and herring gulls are all indifferent to sugar, but parrots, budgies, and hummingbirds like it. Hence, there are differences even within avian species.

Nonnutrient Feed Additives

INTRODUCTION

A feed additive is a substance or mixture of substances other than a basic feedstuff present in feed. The term does not include chance contaminants. Feed additives make feeds better, safer, more efficient and are an important "tool" of feed science. While not new, their increased use has focused public attention on them.

Feed additives are used in scientifically controlled amounts. The amount necessary to perform the needed function is usually small. The safety of the substances is carefully established before they are used in connection with feeds. Many are created by scientists in answer to special problems. Some laboratory-created chemicals are also found naturally in foods. For instance, cheese naturally contains propionates, substances used to retard mold. Whether the additives come from foods or are synthesized, they are chemical in nature.

Some people without scientific background believe that "chemical" means something dangerous or unnatural. Everything in the world is essentially chemical—from the concrete in roadways to vitamins in foods. A poultryman may look incredulous if he were told he had just fed his flock triglyceride esters of palmitic, linoleic, linolenic and stearic acids, but when he becomes aware that the words are simply chemical terms for fats, he begins to understand that feeds are made up of many chemicals. It is almost impossible to prepare high quality poultry feeds without the use of chemical additives because they have become vitally necessary in modern feeds. Some, like vitamins, are essential for good health. Others are needed to protect crops from being consumed by insects. Still others are useful in improving color, flavor, texture, and keeping qualities of feeds.

Improvements in growth, egg production, and hatchability result from enrichment of poultry rations with traces of various chemicals. Chemical additives may be defined as chemicals or drugs other than the known nutrients that provide protein, energy, vitamins, and minerals. These substances are added at the rate of a few pounds per ton of feed, separately or in combination. These additives include medications, mold inhibitors, hormones, and feed stabilizers such as antioxidants. Such additives relate frequently to the environment: oldness or newness of quarters, sanitation or contamination, wire floors versus solid floors, and litter versus no litter. These factors influence growth response and feeding results.

Chemical additives should be added to feeds by competent individuals,

since these compounds may be harmful if fed in excess of recommendations. Growth stimulants which aid in disease prevention are antibiotics, arsenicals, and furazolidone (NF-180).

MEDICATION OF FEEDS

There is general acceptance of the concept that the feed industry provides medication vital for economical poultry production. Poultry producers demand medicated feeds to assist them in disease problems. In the early days, coccidiosis was treated by adding 5% of flowers of sulfur to the feed. Much more satisfactory medicaments have become available since the early days.

Sulfaquinoxaline or nitrophenide, nitrofurazone, arsenosobenzene, and nicarbazin are fed to birds when there is no real outbreak as preventive medication. They should not be used as an excuse to neglect sanitation. These drugs are toxic if fed at too high levels for prolonged periods. Excessive levels produce incoordination in chicks or chicks may appear drowsy. These facts emphasize the need for accurate mixing of the proper amount of each drug. Coccidiostats prevent cecal coccidiosis by *E. tenella.* Intestinal forms are prevented by sulfaquinoxaline by its action on *E. necatrix* and *E. acervulina.*

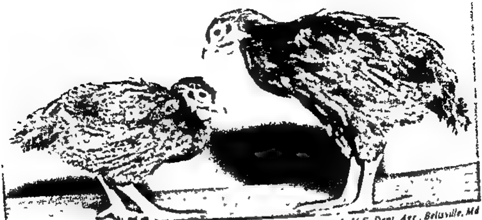
Medicants for blackhead include 4-nitro (4-nitro phenolarsonic acids) and Enheptin-A (2 acetyl amino-5-nitrothiazole). The former is fed as a preventive continuously from hatch to market age, and to breeder turkeys. The latter is used as a preventive beginning at 1 or 2 weeks before birds reach the age when losses usually occur and continuing up to a week before slaughter. Furazolidone (NF-180) in the feed is also effective as a preventive but costs more.

Medicant for *Salmonella* is NF-180. It treats fowl typhoid, paratyphoid, and pullorum in chickens and turkeys, and is fed continuously at a preventative level or for two weeks as a control after an outbreak is first detected.

Phenothiazine in the feed is used against cecal worms; nicotine sulfate against large round worms. Organic tin compounds used for a 1- to 2-day period in the feed show considerable promise for removal of some common tapeworms. Wormers are used for 2- to 7-day feeding periods only. A complete, accurate and rapid diagnosis is an absolute essential to prevent unnecessary loss of birds and loss of profits to the producer.

CHEMICAL ADDITIVES

Poultry feeds may contain several chemical additives, including two or more antibiotics, an arsenical, nitrofuran, antioxidant, and coccidiostat. Most research work has shown benefits from adding each of these compounds singly or in combination. The manufacturers of chemical additives have recommended either continuous or intermittent use of these drugs



Courtesy of Poultry Branch U S Dept Agr., Beltsville, Md

FIG 23 1. RHODE ISLAND RED COCKERELS WHICH RECEIVED DIET WITHOUT (LEFT) AND WITH (RIGHT) 20 GM AUREOMYCIN PER TON OF FEED; AT 6 WEEKS OF AGE CHICKS WEIGHED 590 AND 765 GM RESPECTIVELY

when disease strikes. Chemical additives make the biggest contribution during the very early growth of the birds. Cost of antibiotics may be less than 1c per bird which is low-cost insurance to protect them during their most critical growing period.

Such chemical additives are also used in laying rations to stimulate egg production and the general health of the flock. Marked improvement in egg production from these drugs has usually been observed when production has dropped sharply. Less response is obtained when production is high. At 1968 prices, it took 4% more production just to pay for the added drug. This increase in production is difficult to achieve if the birds are already laying at 70%. Before feeding these drugs it is advisable to submit a few representative birds from the flock to a poultry pathology laboratory for diagnosis of the disease condition.

Some representative products are as follows:

(1) Antibiotics, arsenicals and furazolidones for growth promotion:

Drug	Manufacturer	Levels in Feed for Growth (Gr per Ton Feed)
Aureomycin	American Cyanamid	10
Terramycin	Chas. Pfizer	10
NF-180	Hess and Clark	10
Zinc bacitracin	Commercial Solvents	4
Procaine penicillin	Merck, etc.	4
Gallimycin	Pfizer	10
Pro-Strep	Merck, CIBA, etc.	4
Tylan	Elanco Products	10
Arsanilic acid	Abbott Laboratories	90
3-Nitro phenylarsonic ac.	Dr. Salsbury	45
Sodium arsanilate	Dr. Mayfield Laboratories	45-90

(2) Antioxidants which help protect fats from rancidity and fat-soluble vitamins A, D, E, and K from destruction:

Drug	Manufacturer	Level in Feed (% Active Drug)
BHT	Eastman Kodak	0.01
Santoquin	Monsanto	0.01

(3) Medicaments for control of coccidia:

Drug	Manufacturer	Recommended Levels for Prevention (% Active Drugs, and Lbs per Ton)	
Amprol	Merck	0.0125	1
Nicarbazin	Merck	0.0125	1
Sulfaquinoxaline	Merck	0.0125	1
Zoaline	Dow Chemical	0.0125	1
Unistat	Dr. Salsbury	0.06	2
Megasol	Lederle	0.0126	1
NFZ	Hess and Clark	0.0055	1
Buqinolate	Norwich	0.00825	1.6

(4) Drugs for controlling or treating blackhead in turkeys:

Drug	Manufacturer	Level Used for Prevention (Lb per Ton)
Carbosep	Whitmoyer	2
Histostat	Dr. Salsbury	2
Cyzine	Lederle	3
Hepzide	Merck	2

(5) Drugs for internal parasite control:

Drug	Manufacturer	Level Recommended (Lb per Ton Feed)
Piperazine	CIBA, Vineland	2.2
Wormal	Dr. Salsbury	20
Hygromycin	Elanco	1.5

Worms are a source of economic loss to poultrymen who sometimes worm pullets before housing. Wormal contains three active drugs effective against round, cecal, and tapeworms in chickens and turkeys. It should not be fed to laying birds in high production (65% or more) since it will depress rate of lay. Hygromycin is also effective in treating capillaria worms when fed at the rate of 12 gm per ton of feed for 8 weeks.

(6) Mold inhibitors: These chemicals are sometimes added to poultry feeds to protect against mold development. Molding occurs when feed is too moist or is shipped or stored under adverse conditions of high humidity and high temperatures. Molding causes heating of feeds which results in destruction of vitamins and an impairment of the availabilities of certain other nutrients. Some species of mold are definitely poisonous; others harmless or beneficial. It is safest to prevent development of mold in feed for poultry.

(7) Hormones or hormone-like substances to quiet birds and improve fattening characteristics: Estrogens are hormones which in nature are produced by the ovaries of all females just before the hens start to lay. Estrogens are responsible for the deposition of large amounts of fat in the muscle, under the skin, and in the visceral and abdominal sections. Synthetic estrogen-like compounds are available and are used in fattening both males and females. In older birds this results in increased weight gains and a reduction in the number of pinfeathers on dressed carcasses.

Estrogen-like compounds added to some poultry feeds and diethylstilbestrol implanted in poultry affect fat deposition. Since stilbestrol is not effective when administered orally, dienestrol diacetate (Lipamone) is used in feeds to improve market finish. There is no improvement in feed conversion in broiler age birds and little benefit on rate of growth. Males of boiler age fail to comb out and resemble pullets. The rather high cost of estrogen for feeding discourages widespread general use. This has been described as "chemical caponization" of males, although the effect is due to the presence of female hormones rather than the absence of male hormones. Five-week-old broiler chicks have been implanted with one pellet containing 51 mg of diethylstilbestrol under the skin at the base of the skull, and have been marketed commercially but this procedure is not approved by FDA for use at present. In the practical feeding of estrogenic compounds, the rate of use is 30 to 70 mg per lb of feed for a period of 2 weeks.

Antibiotics

Years ago, Pasteur had suggested that human diseases might be cured by marshaling microbe against microbe. Researchers looked for chemical agents from microbes friendly to man to destroy disease germs. Antiseptic chemicals of biological origin were the world's first antibiotics. But little was done with them until 1928 when Dr. Alexander Fleming, a bacteriologist at St. Mary's Hospital in London, England had a profoundly important experience. In one of his petri dishes which contained bacteria, there was a clear ring in the center of the dish showing where germs in the vicinity of the invading substance had been destroyed. The interloper in the dish was a penicillin mold frequently found in the air. He extracted a chemical from the mold which had killed the *Staphylococcus* organisms and he finally obtained a tiny quantity of a brownish secretion. During the

course of World War II Fleming showed that penicillin worked wonders on laboratory animals and humans.

Since Britain's production facilities were devoted to war work, the United States, who was not at war at the time, devoted its mass production techniques to the solution of the problem. But the penicillin was unstable and it was necessary to coax the penicillin mold into producing more penicillin. Finally, the mold was cultivated in large aerated tanks. A new strain of penicillin was then found on a moldy cantaloupe in a Peoria, Ill. market. It thrived in tanks and eventually gave much more penicillin than the original strain.

With penicillin a success, scientists set out to find other antibiotics capable of fighting diseases against which penicillin was ineffective. Molds, yeasts, actinomyces, bacteria or similar microorganisms are available in soil, lakes, streams, seas, and in the air. No microbe is without enemies and none is invulnerable to attack.

Microbes are considered members of the plant kingdom, even though they are microscopic and without chlorophyll. Molds are more nearly akin to the layman's conception of plant life and look like trees sending out threadlike branches of white, yellow, blue, green, gray, red, black or brown. Having achieved some growth, they are visible to the naked eye, as in the case of mold on bread. Molds reproduce themselves by means of spores, a process roughly equivalent to seeding in plants. Spores are 1/5,000 in. in diameter and dispersed by actual explosion. Survival of spores depends on the medium and environment on which they land by wind, water, or a passing insect, bird or animal. The penicillin spores which were planted on Dr. Fleming's petri dish were able to flourish because the dish contained a nutrient on which it could feed.

Actinomyces are a good deal like molds in general appearance and propagated in a somewhat similar manner. They form chains of spores like beads of a necklace. Yeasts are colorless, egg-shaped plants produced by buds that develop into whole cells. Bacteria simply divide and produce new cells from the original ones. Under the microscope they appear as dots, corkscrews or rods. Under favorable conditions, some of the organisms multiply once every half hour. Bacteria may be dyed with a stain named after Professor Gram, a Danish bacteriologist. Those dyed are known as gram-positive and include germs which cause boils, abscesses, pneumonia, venereal diseases, scarlet fever, and rheumatic fever. Penicillin is effective against these diseases but is useless against the gram-negative bacteria which are not stained by the dye and cause diseases such as typhoid, undulant fever, and certain types of pneumonia.

Professor Waksman of Rutgers University and his students isolated from the throat of a chicken *Streptomyces griseus* which produced the anti-

biotic, streptomycin, effective not only against gram-negative bacteria resistant to penicillin but against *Mycobacterium tuberculosis*, the organism causing tuberculosis.

From all over the world have come hundreds of thousands of soil samples for evaluation. Molds which appear promising are allowed to grow in the presence of disease germs to find whether they produce the "ring of inhibition" which is a signal that an antibiotic is at work. In 1949, a bit of earth from the Midwest was found to contain an actinomyces worthy of intensive investigations. The germ was named *Streptomyces rimosus* and the canary yellow crystals of the antibiotic called terramycin attack both gram-positive and gram-negative bacteria, rickettsia, and the large viruses which cause psittacosis.

Mode of Action of Antibiotics.—Among scientific subjects, the method of discovery and introduction of antibiotics in medicine and feeds have had a picturesque history. The theory that microorganisms, antagonizing each other on an agar plate, should yield drugs useful in the treatment of disease, recognizes the universal awareness that there exists in the biological world many balancing forces which assure some sort of equilibrium between living things. This was recognized by Pasteur, who in 1873 proved that microorganisms commonly present in soil affected the anthrax bacillus in such a manner as to render it unable to establish disease in animals. He clearly recognized that it is possible to inhibit selectively certain types of microbial growth by the use of proper chemical substances devoid of any inhibitory act on other microbial species.

Ehrlich and Wygant suggested that drugs act by competing in some of the essential metabolic processes of the parasite, and hence interfering with its nutrition. Vigorous chemotherapy may bring about an almost complete elimination of the normal intestinal flora which is then replaced by other kinds of bacteria or fungi. There is ground for the view that the drugs enhance growth by inhibiting certain microbial activities which in some way or another exert a deleterious effect on their economy as a whole.

The manner in which feeding antimicrobial drugs increases the rate of growth of poultry and renders more efficient their utilization of food is not fully understood. Antibiotics are not nutrients in the ordinary sense. They are chemicals or drugs produced by living organisms which destroy other living organisms. Commonly used in the feed industry are procaine penicillin, oxytetracycline, chlortetracycline, and bacitracin. They are used in two ways: (1) high level inclusion in the diet over a short period as a medicine to help cure a particular infection; and (2) low levels continuously in the diets of birds throughout the feeding period for improved poultry production. When antibiotics are used, it is imperative that the

directions of the supplier be followed. The feed industry is particularly concerned with low level usage.

Veterinarians use antibiotics to treat diseases which is outside the scope of this discussion. When antibiotics are put into feed at low levels, it is for growth promotion, not the treatment of any disease or from a medical standpoint.

In the beginning of antibiotic usage in feeding, researchers obtained differences of as much as 18 to 25% in the growth rate of birds. Now, it is unusual to get a 3% difference. Actually, what happens is that the environment is improved due to the use of antibiotics. When first used, birds on the control, nonantibiotic rations started from a lower base. Thus, percent improvement was better. But antibiotic-fed birds are growing better than ever which is the important thing.

Poultry have achieved through the processes of revolutionary adaptation some sort of equilibrium with the microbial species in their environment and in particular with the microorganisms which they constantly harbor in their tissues. This equilibrium does not necessarily result in the best possible state of health. The equilibrium corresponds to a compromise between many conflicting necessities. The presence in the tissues of large numbers of relatively innocuous microorganisms helps in controlling the multiplication of other species with pathogenic potentialities. Many of the microorganisms normally present in the chickens have mild deleterious effects which although compatible with "normal" performance, interfere somewhat with the optimum performance of metabolic functions. Therapeutic measures which eliminate or attenuate these deleterious influences bring about indirectly greater metabolic efficiency.

Use of Zinc Bacitracin.—Low level feeding with an antibiotic such as zinc bacitracin is usually all that is needed to control the disease level normally encountered in good poultry operations. This substance is mainly effective in the intestinal tract. Ulcerative enteritis may call for somewhat higher levels of this or other antibiotics. Once the invasion of the bloodstream by pathogenic organisms has occurred, high levels of highly-absorbable, usually broad-spectrum antibiotics are needed. These are administered in such a way as to promote high blood levels of the antibiotic, such as by injection. The major growth promoting effects of low level feeding of antibiotics occur because of the beneficial effects of these antibiotics upon the microflora of the intestinal tract. The mere fact that zinc bacitracin, a practically nonabsorbable antibiotic, is effective in growth promotion should be ample evidence in support of this conclusion. Antibiotics vary in their stability and rate of absorption in the intestinal tract. No residues are present in meat or eggs with combinations commonly used as feed supplements.

Use of Chlortetracycline.—In 1950, researchers at American Cyanamid reported improved growth rate of young chickens when they were fed low levels of chlortetracycline (Aureomycin). In England, when birds were raised in quarters which had been in use for sometime and exposed to infections which caused no visible pathology, growth of chicks was depressed. When an antibiotic was given, the birds grew normally. The antibiotic does not stimulate growth but lessens the conditions that retard growth. In this way the birds approach their optimum efficiencies, for the more severe the growth depression, the greater the response to antibiotics.

Aureomycin inhibits a wider variety of microorganisms and promotes growth in a wide variety of animals. Penicillin and bacitracin affect a more narrow group of bacterial types and have a smaller growth-promoting effect than that of Aureomycin.

Bacitracin and streptomycin are not absorbed and thus do not reach the bloodstream if fed at the usual commercial levels. Penicillin, although absorbed when fed is less effective than the tetracycline drugs in the prevention and control of diseases because of its narrow spectrum. It is restricted especially to gram-positive organisms.

"Narrow spectrum" is applied to penicillin and bacitracin and has been used to signify full activity against gram-positive bacteria and absence of activity outside this range. Neither assumption is completely true. The activity is uniformly strong but not complete throughout the gram-positive range, but is by no means restricted to that range. "Broad spectrum," as applied to the tetracycline group, implies strong activity throughout the range of the infective agents. This is not the case. The tetracyclines attack a considerable range of gram-positive bacteria, but this activity varies markedly from one organism to another.

Potentiation of Antibiotics.—The concentration of tetracyclines in the blood serum of poultry can be increased or "potentiated" by reducing the percentage of calcium in the ration and by substituting calcium sulfate and a soluble sodium phosphate for the commonly used calcium carbonate and calcium phosphate. Potentiation is limited by the necessity of supplying enough calcium to meet the animal's requirement. Within this limitation, the method can be used to potentiate the antibiotic level more than twofold. More effective potentiation up to tenfold can be obtained through the use of certain sequesterants or chelating agents. However, none of these have thus far found practical application due to cost. The inhibiting action of calcium on antibiotics absorption can be prevented by the use of terephthalic acid as a feed additive. However, its use in feed thus far has not been cleared by the U.S. Food and Drug Administration. Without potentiation, the effectiveness of tetracyclines against systemic diseases is sharply limited due to poor absorption into the bloodstream.

"Potentiation" increases the concentration of an antibiotic in the blood and tissues of animals by adjusting the composition of the ration. It is confined almost entirely to the tetracyclines: chloretetracycline (Aureomycin), oxytetracycline (Terramycin), and tetracycline, itself. Other commonly used antibiotics do not respond to potentiation by ration adjustments. The solubility of tetracyclines in the digestive tract is inhibited by the presence of bivalent metals including calcium, magnesium, iron, copper, manganese, and zinc. It follows that the tetracyclines can be potentiated by decreasing the levels of bivalent metals in the ration or by adding to the ration certain sequestering (chelating) agents which inactivate the minerals after they reach the digestive tract. Of the inhibiting metals commonly present in the digestive tract, calcium is by far the most abundant due to the use of calcium carbonate and calcium phosphate as feed additives.

Aureomycin produces significantly higher blood concentrations in low calcium rations than the same levels of Aureomycin incorporated into commercial broiler feeds containing commonly used levels of calcium. The rate of absorption of Aureomycin can be augmented by a calcium sequestering material such as EDTA or its salt.

Lowering the calcium level or using a calcium salt, such as the sulfate, which does not dissolve in the acid portion of the gastrointestinal tract, yields a lower calcium ion concentration and thereby minimizes the interference of calcium with absorption of Aureomycin. Terephthalic acid enhances the blood concentration of antibiotics and permits the diseased animals to be more economically controlled.

The potentiating program offered by an antibiotic manufacturer for starting and growing chickens is as follows: starting with the first feed through the third week of life, provide Aureomycin, 200 gm per ton in the feed which should have total calcium content of 0.8%. All added calcium should be from calcium sulfate. Total phosphorus should be 0.6%. Beginning with the 4th week and continuing to market for broilers or to 17 weeks for replacement pullets, use 0.02% nitrophenide in the feed or Arzene premix (1 lb per ton) to prevent acute outbreaks of coccidiosis. For turkeys, the program is the same, except that total calcium at the beginning should be 1.0% and phosphorus 0.8%. After 4 weeks, add Enheptin-A premix (15%, 2 lb per ton) to prevent outbreaks of blackhead.

When feed consumption starts to increase sharply or during outbreaks of specific diseases such as paratyphoid, a decision should be made whether it may be more effective to use higher levels of effective drugs in the feed or drinking water. This could represent sizable savings if mortality is reduced or the time of infection is shortened.

The amount of antibiotics used in feeds is only a small fraction of the

levels for treatment of disease. Growth stimulation is greatest during the first few weeks of life. Slower growing chickens not receiving antibiotics gradually overtake the others with the result that at about 12 weeks of age the growth difference disappears. By the time birds are 20 weeks old there are no significant weight differences between those fed antibiotics and those that did not get antibiotics. Thus, the only advantage with respect to flock-replacement-chickens is to decrease mortality and improve feed efficiency.

The efficiency of feed utilization is generally increased when chicks are given antibiotics, probably due to the improved rate of growth of the chicks, since the faster chicks grow, the better the feed utilization. The variability in chicks receiving antibiotics is somewhat less than in the control chicks not receiving antibiotics.

Dosage Levels of Antibiotics.—Two dosage ranges can be defined: low (20 to 50 ppm), and high (50 to 200 ppm). The most market production increases have been achieved at the higher levels, but profitability has not necessarily increased at the same time. Antibiotics are beneficial in reducing early chick mortality in disease situations and also in times of stress. Their use is indicated after any shock or upset such as overheating, chilling, vaccination, worming, and debeaking. They are fed 2 or 3 days prior to the period of stress and 2 to 5 days following stress, depending on the condition of the birds.

Reports are conflicting concerning the effects of antibiotics at low levels in laying rations. When adequate rations are fed, they exert no favorable effect either on egg production or hatchability. Antibiotics enhance the utilization of calcium, phosphorus, and manganese, possibly because the acidity of the small intestine and ceca is increased.

The manner in which antibiotics react on the microorganisms in the intestines of apparently normal animals and improve nutrition is somewhat of a mystery. Some believe that it is mainly due to the weakening or destructive effect of antibiotics on the bacteria of the digestive tract. Reduction of harmful bacteria and encouragement of beneficial bacteria are involved, but not all scientists agree on this. The anatomy of the gut is changed with antibiotic feeding; the intestinal wall usually gets thinner than if none are fed. There has been much controversy as to the propriety of continuously using a drug which will destroy harmful microorganisms. If resistance is developed to it, the drug may not be effective in an epidemic.

Antibiotics do not change significantly the total number of microorganisms in the intestines, except for one kind (clostridia). Antibiotics spare the requirements for protein, certain vitamins and minerals, make the intestine more acid, improve absorption, and stimulate bone growth. A certain level of contamination is necessary for them to be beneficial.

The mode of action of antibiotics may differ quite widely depending upon

the disease level. Antibiotics may act as follows: (1) favor the growth of nutrient-synthesizing and inhibit the growth of nutrient-destroying microorganisms; (2) inhibit the growth of microorganisms that produce excessive amounts of ammonia and other toxic nitrogenous waste product in the intestine; (3) improve availability and/or absorption of certain nutrients; (4) improve feed or water consumption, or both; and (5) prevent actual pathological disease.

Antibiotics improve growth as much as 30% in the marginal diets and 3–6% in more abundantly fortified rations. Feed efficiency is also improved. However, some baffling inconsistencies in growth response are obtained. A "new" environment (building or facility where no poultry had previously been raised) prevents manifestation of the antibiotic effect. Germ-free chicks also show no benefit. Where organisms from the contaminated environment were fed to the birds without antibiotics, growth is depressed. Thus, the antibiotic effect is related in some way to the microflora, possibly through destruction of the harmful organisms or indirect stimulation of the beneficial ones which may synthesize needed nutrients.

Resistance to Antibiotics by Organisms.—Because the inside of the egg is sterile, experimentally kept fowls can be reared with no demonstrable population of microorganisms in the gut or in the environment. Such birds permit investigation of digestion, nutrition and well-being in the presence or absence of microbial population. By such methods, it has been established that antibiotics exert their growth-promoting effects through their action on the gut population since in the absence of microorganisms, they have no effect. Thus, the expression "growth promoting" is a misnomer. Apprehension of possible future emergency from the development of resistant strains from long continued use of feeds containing antibiotics is widespread. If antibiotic-resistant strains of pathogenic microorganisms become established in farm livestock because they had been fed antibiotics, the possibility exists that an epidemic may occur with no therapeutic agents available for treatment. But no good evidence is at hand that the development of antibiotic resistance in microorganisms is occurring. Hazard to the well-being of antibiotic-fed chickens arises from the potential therapeutic inefficiency of that type of antibiotic, should they become diseased.

Some investigators have reported a lessened growth response to antibiotics following prolonged usage. They think that this is due to the development of resistant strains of organisms. But birds fed no antibiotics grow as well as those fed antibiotics if raised in an environment where antibiotics have been used continuously for some time. Thus, it is possible that there may be a temporary eradication of depressive microflora rather than the development of resistance. Continuous use of antibiotics is necessary to prevent reinfestation of facilities with harmful microflora.

Possible antibiotic-induced bacterial resistance is of interest because of human health aspects. Tetracyclines increase resistance in bacteria belonging to the *Escherichia coli* and to *Salmonella* groups. The mechanisms of resistance is a complex problem. A few inherently resistant cells in a bacterial population may take over when sensitive cells are killed off. The resistant strains are no more pathogenic than sensitive ones. A mixed population of organisms appear in the alimentary canal of newly-hatched chicks a few hours after they have been given food and water, and stable flora is established within the first 48 hr of life.

Growth-promoting effects of antibiotics are correlated not simply with elimination of *C. welchii* but rather with the suppression of its toxin production. Growth of germ-free birds is depressed on contamination with *C. welchii*, an effect that is reversed by dietary penicillin. A mixed contamination of *E. coli, Streptococcus liquefaciens* and *Lactobacillus* does not affect the growth of otherwise germ-free chicks. These results suggest the suppression of *C. welchii* is closely concerned with the growth-promoting action of antibiotics. It is unlikely, however, to provide the full explanation.

Antibiotic supplementation has the same effects in rations consisting only of vegetable protein as in those containing animal protein. No significant difference in effectiveness between different antibiotics is observed during the growth of broilers to eight weeks of age. Antibiotic supplementation has no effect on brooding and hatching results but it leads to a slight increase in the body weight of the hens. Responses under average sanitary conditions and balanced diets vary between 2 and 8% in growth and 2 to 4% in feed conversion. Antibiotics have also been shown to counteract marginal deficiencies and imbalances in the diet.

In summary, antibiotics inhibit or destroy organisms which produce subclinical infections. They suppress organisms which produce toxic reactions which cause slowing of growth of the host animal, and produce an increase in number or activity of organisms which synthesize certain growth factors which are eventually made available to the host. They invade organisms which compete with the host for available nutrients. Good evidence is available to support the first possibility; however, some findings also support the latter.

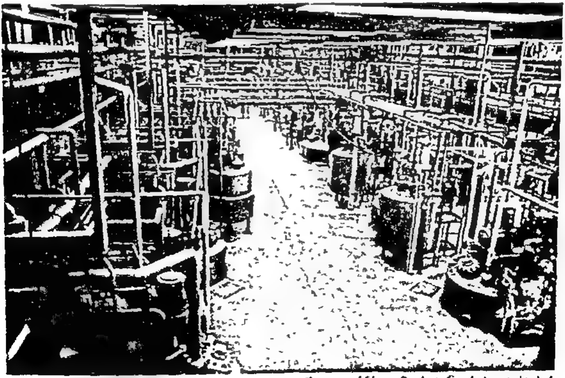
Antibiotics have a sparing effect on the requirements of the proteins and certain minerals and vitamins, although the antibiotic growth effect is obtained when the diet is supplemented with more than sufficient amounts of the known vitamins. The tissues of the antibiotic-fed animals are of normal composition, although there is a decrease in the weight without a change in the length of the gut.

The practice of feeding antibiotics to poultry is widespread and so far

no untoward effect on public health has resulted. Detectable amounts of aureomycin are not found in meat even after poultry are fed antibiotics at levels far higher than usual. Furthermore, most antibiotics are destroyed by cooking. Reproduction in poultry does not appear to be affected by feeding antibiotics. The combination of procaine penicillin and streptomycin sulfate has a broad spectrum range of activity and gives an effect greater than either antibiotic alone. In field tests, it has been found economical to use this combination. Usually mortality and morbidity are lowered while birds maintain egg production and growth gains on less feed.

Aureomycin, penicillin, and streptomycin are ineffective in promoting the growth of chick embryos when injected under sterile conditions. Bacitracin and streptomycin which are not readily taken up from the gut have a growth-promoting effect when added to the diet of chicks. Hydrolysis with penicillinase leads to a disappearance of the growth-promoting activity of penicillin in chicks and its antibacterial potency is also destroyed.

"Nutritional" levels of antibiotics are 2 to 10 gm per ton of complete feed. These have their greatest effectiveness in starting diets for chickens and poults. Whether antibiotics are used with other classes of poultry depends on the disease level and the amount of stress. Antibiotics are relatively low in cost and perform under a wide range of conditions.



Courtesy of Elanco Products Co., Indianapolis, Ind.

FIG. 23.2. LARGE SCALE, SOPHISTICATED EQUIPMENT IS THE KEY TO ECONOMICAL PRODUCTION OF ANTIBIOTICS

Widespread use of antibiotics in animal feeds presents a potential public ealth hazard which has not, as yet, been fully evaluated. At the present me, there is no evidence linking use of antibiotics in animals to human isease. The public health hazard stems from the possibility of resistant ›rganisms in animals being transferred to human beings. This raises the ›ossibility of a microbial population occurring in human beings which vould be partly, if not largely, resistant to normal therapeutic agents. Resistance to certain drugs which some bacteria possess can be transferred to other bacteria by conjugation as well as genetically. In other words, one organism can through conjugation transfer the resistance it has to one or more drugs to other bacteria of the same species or in some instances to other species of bacteria. Regulations are being proposed to deal with this matter, particularly with the injectable preparations containing penicillin, streptomycin, and dihydrostreptomycin, chlortetracycline, tetracycline, bacitracin, and chloramphenicol. The basis for the proposed action is because the residues of these drugs remain in edible tissues of treated animals for an unknown length of time, sometimes for more than 75 days. Aqueous penicillin preparations must be labeled with a five day withdrawal time.

TABLE 23 1

AVERAGE LEVELS OF AUREOMYCIN IN BLOOD SERUM OF POULTRY AS AFFECTED BY AUREOMYCIN LEVEL IN THE RATION

Aureomycin in Feed (Gm per Ton)	Aureomycin in Poultry Blood Samples (Mcg per Ml)
0	0
25	0 002
50	0 0025
100	0 0045
200	0 009
400	0 170
500	0.200
1000	0 430

TABLE 23.2

INFLUENCE OF CALCIUM, PHOSPHORUS AND TEREPHTHALIC ACID (TPA) LEVELS ON CONCENTRATION OF TETRACYCLINE ANTIBIOTICS IN CHICK BLOOD SERUM

% TPA in Feed	Antibiotic in Feed (Gm per Ton)	% Calcium in Feed	% Phosphorus in Feed	Conc of Antibiotics in Chick Blood Serum (Mcg per Ml)	
				Aureomycin	Terramycin
0	100	1.18	0 8	0 036	0.15
0 375	100	1.18	0 8	0 092	0.201
0	200	1.18	0.18	0.065	0.193
0 375	200	1 18	0 8	0.232	0.373
0	100	0 18	0 8	0.130	0.237
0 5	100	0.18	0.8	0.209	0 400
0	100	0 18	0 18	0.260	0 433
0 5	200	0.18	0 8	0.484	0 668

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Arsenicals

Arsenicals, widely used as chemical additives in poultry rations, are 3-nitro-4-hydroxy phenylarsonic acid (3-Nitro) and *p*-amino phenylarsonic acid (arsanilic acid). These compounds improve growth and market grades of broilers and produce precocious combing with bright red combs and wattles. Capillaries are enlarged and engorged through the dilator effect of arsenic. Arsenicals probably function in a manner similar to antibiotics, although evidence is not as far developed on their mode of action. The amount of arsenic retained within the tissue is quite low—about that naturally found in some seafoods. Arsenicals are required to be removed from the feed five days before slaughter during which time practically all of the chemical is excreted.

The ratio of arsenic-producing toxicity to that producing desirable results in poultry is fairly small, much smaller than in the case of antibiotics. Only simple precautions against swallowing and inhaling the arsenicals are required in the feed mill during operations of weighing and mixing of feed, but care should be exercised in the usage of arsenicals. It is claimed that arsenicals improve pigmentation but this is controversial. Apparently, arsenicals do not promote an increase in pigmentation under conditions where disease is not present. Arsanilic acid is less toxic than 3-Nitro. Arsenicals are approximately equal to antibiotics in promoting growth.

Antibiotics and arsonic acids produce fairly comparable changes in the intestinal flora of chickens. Canadian researchers observed increases in lactobacilli counts and a fall in pH of cecal contents. Texas workers reported a marked drop in total clostridia per gram of chick feces. *Clostridium perfringens* is a possible inhibitor of animal growth, and arsenicals and antibiotics greatly decrease the numbers of this organism in the intestinal tract of turkey poults. More research, particularly standardization of techniques, is needed to develop the promising leads that implicate specific bacterial groups.

Antibiotics cause a significant sparing effect for the B-complex vitamins but arsenicals do not. Arsanilic acid has no unfavorable effects on egg production or hatchability when fed to pullets for 11 weeks. Accumulation of arsenic in eggs and tissues is proportional to the amount in the ration and well below allowable levels. In general, toxicity appears to be related to the amount of arsenic deposited in tissue. Arsanilic acid is tolerated up to 0.1% of the diet in chicks and up to 0.02% in the diets for turkeys. Arsanilic acid and 3-Nitro offer partial protection against selenium at 10 ppm of the diet. Arsanilic acid acts similarly to procaine penicillin in decreasing the need for thiamine in chicks.

Arsenicals improve production on low-protein rations but not on normal protein rations. With turkeys, antibiotics and arsenicals generally pay for themselves when fed on a low level basis. Like antibiotics, the addition of arsonic acids is more effective where conditions are suboptimal and egg production can be improved. Where production, egg size and quality, livability, and progeny performances are excellent, they give less or no response. Most experiments have been carried out under conditions probably superior to those found in the field. Consequently, it is possible that their greatest value may be derived under more adverse and diverse conditions as with commercial production.

Furazolidone

It is not often that a drug lives up to its advance billing but furazolidone has done so. Three general uses are: growth stimulation, disease prevention, and disease treatment. Furazolidone is perhaps the most versatile antimicrobial that is now available. It has the definite advantage of being relatively safe although proper safeguards and dosage are important. It combines well with other drugs likely to be used in feeds.

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Antioxidants

Rancidity of fat in feeds is undesirable because palatability is lowered and vitamins may be destroyed. Free fatty acids, the direct product of rancidification, are not in themselves harmful but the ozonides, peroxides,

and similar compounds are. Antioxidants such as butylated hydroxyanisole (BHA) and diphenylparaphenylelediamine (DPPD) added to fats and feeds are used to help protect their quality. They are also added to dehydrated alfalfa meal to protect its carotene content. Antioxidants do not themselves function as nutrients, they protect certain nutrients from destruction.

Antioxidants are chemical compounds which have the property of preventing the oxidation of another substance by preferentially accepting oxygen or electrons and thus breaking the chain reaction which otherwise would destroy the compound in question. They are commonly used to prevent the oxidation of fats or fatty acids. In 1924, it was demonstrated that vitamin A was destroyed by oxidized fats and later in 1938 that the degree of destruction parallels the degree of unsaturation of the fat. The degree of oxidation is determined through what is known as the peroxide number which is a chemical term denoting a measure of the amount of oxygen absorbed by the fat.

Vitamin A is destroyed in the gut of the bird as well as in the feed in the presence of unsaturated fats. In the study of vitamin E, research workers became aware of the fact that vitamin E acted as an inhibitor of autoxidation of fats. Tocopherol also protects carotene in the intestinal tract by virtue of its antioxidant properties.

Exudative diathesis in chicks is a nutritional disease which preferentially affects the chick's adipose tissue. Exudative diathesis does not occur when the diet contains sufficient vitamin E or when fat is not present in the diet. When vitamin E is in sufficient quantities in the diet, no peroxide is demonstrated in the fatty tissues. Another nutritional disease of chicks which occurs with the same type of diet which produces exudative diathesis is encephalomalacia ("crazy chick" disease), which was first described in 1931. Vitamin E in the diet prevents this disorder as does vitamin C, nordihydroguariaretic, and methylene blue, all of which have some antioxidant activity.

Antioxidants prevent the development of encephalomalacia, improve the utilization of vitamin A from fish oils, aid in the development of a good skin and shank color in broilers, and enhance the utilization of carotenoid pigments in pigmentation. Antioxidants such as vitamin E are a natural product; synthetic antioxidants include BHT, BHA, (butylated hydroxytoluenes) and ethoxyquin. The need for antioxidant protection is increased when highly unsaturated fats or oils are included in the ration.

The interchangeable role of certain antioxidants and vitamin E applies to turkeys as well. Some synthetic antioxidants possess vitamin E-like properties but not all of the symptoms are considered to be indicative of vitamin E deficiency response to them. Among these is exudative diathesis in chicks which is chiefly a selenium deficiency, the factor 3 of Schwartz. The requirement for biological antioxidants including vitamin E is depen-

dent upon the content of polyunsaturated fatty acids or their oxidation products. Linoleic acid has been noted as a specific cause of encephalomalacia. The accumulation of auto-oxidizable lipids in muscle is a primary criterion in the production of dystrophy.

Early work indicated that DPPD was relatively nontoxic to chicks. However, it was found to induce prolonged gestation in rats and cause high mortality of both mother and pups. As a result of these effects on mammalian production, the US Food and Drug Administration requested that feed use of DPPD be discontinued. BHA and BHT have a long history of safe use in fats and oils and are added often in combination to improve stability of fat soluble vitamins.

Ethoxyquin is an antioxidant used for the preservation of carotene in dehydrated alfalfa meal. It is used at a level not to exceed 0.0125% in poultry feeds. The best known and most effective of the naturally-occurring antioxidants are the tocopherols (vitamin E) found in cereal grains, grasses, and other products, and also the phospholipids including vegetable lecithin found in soybeans, raw oat flour, yeast, animal tissues, legumes, grasses, and gums. Gum guaiac is an antioxidant used in lard and other liquid fats and dehydrated fats and foods.

Combinations of antioxidants sometimes prove more effective than the additive effect of the two individual antioxidants. This is known as synergistic effect. Synergism is assumed to involve the chemical alteration of the antioxidant itself or involves the tying up of certain metallic ions known to catalyze oxidative reactions.

Many antioxidants are used to help protect nutrients. Antioxidants become additional ingredients in the total feed mixtures and are subject to feed control regulations. They must be cleared for safety and usage because some of the most effective antioxidants are also very toxic to poultry. The use of antioxidants permits high levels of fat to be used in feeds without ill effects.

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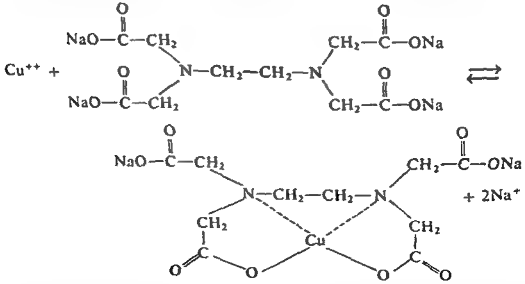
Surfactants and Chelation

Surfactants.—Some surface-active agents possess the property of stimulating growth of chicks. As in the case of other growth stimulants, their effect is usually up to only 12 weeks of age. Some of the growth stimulants already described are surface-active. There are a great many surface-active compounds and much more research will be required before definite conclusions can be drawn concerning their value in practical poultry rations. Growth stimulation cannot be claimed generally for surfactants but is specific for particular compounds of this type. Some of these have been found to be effective; others growth depressing. In the case of effective products, growth increase has not been greater than that produced by antibiotics. No benefit is gained by feeding both an antibiotic and a surfactant.

Chelation.—Chelation plays a major role in increasing or decreasing the biological availability of metals. Chelation is the reversible reaction between polyvalent metal ions and polyamino-carboxylic acid to form within the molecules one or more ring structures incorporating the metal ions. The name is derived from the Greek "chele" meaning claw which describes the claw-like structure of the chelate molecule. Chelating agents are well known industrially but their application in the field of nutrition is not well developed.

As an illustration of chelation, copper as the cupric metal ion reacts with EDTA (ethylenediamine tetraacetic acid) in the following manner:



Chelates are of major importance in the regulation of many of the reactions taken for granted. The amount of calcium and phosphorus needed by osteoblasts for the deposition of bone is provided at the site of deposi-

tion. The ratio of exactly 2 parts of calcium and 1 part of phosphorus would precipitate at the pH of the blood, except for chelates.

Chelates from Antibiotics.—Tetracyclines and other antibiotics form chelates with calcium and other polyvalent cations which interfere with antimicrobial activity of the antibiotic. One of the primary functions of the polyvalent essential cations in metabolism is to form chelates between enzymes and substrates and this is an important mechanism through which trace elements act as activators of enzyme reaction. The reaction compounds between the sugars and lysine which render lysine unavailable for incorporation into tissue proteins serve a useful purpose since this type of sugar: amino acid compound is an excellent chelating agent. Thus, many chelating agents perform useful and even vital functions in the animal body. Others may cause drastic interference with metabolism. Until more research has been done, attempts to make practical use of chelates in animal nutrition may produce unexpected results.

Use of EDTA.—Natural materials also contain chelates which are as effective as EDTA in improving the utilization of trace minerals. EDTA not only improves the effectiveness of the zinc already present in the diet but of the added zinc as well. A casein-phytic acid complex in a chick diet causes severe growth depression which can be counteracted by the addition of zinc to the diet. One theory involves the absorption of the chelate itself. After absorption, the various enzymes and transporting systems within the animal may have stability constants sufficiently high to remove the metal from the chelate and make it effectively available to the animal. EDTA is absorbed by chickens and turkeys. Trace minerals are solubilized by the addition of chelating agents to the diet and absorbed in the chelate form.

Chelation is also recognized as important in the antibiotic field. The majority of antimicrobial compounds are metal-binding agents and part of their beneficial and detrimental properties may be related to this function.

While phytic acid has been implicated as a factor in the availability of zinc, it is not known whether phytic acid alone or in combination with protein is the detrimental moiety. The addition of EDTA to diets containing marginal levels of manganese and copper improves the utilization of these elements also. On the other hand, the addition of EDTA to diets marginal in iron depresses growth of chicks and causes a lowered hemoglobin level, which can be overcome by the addition of higher levels of iron. It is certain that chelating agents can alter the availability of certain minerals.

Mode of Action of Chelates.—Much more work needs to be done to determine interrelationships of various mineral elements in the presence of chelating agents and to determine the stability constants of various com-

ponents with which chelating agents must compete when they are added to biological systems. While organic chelates are relatively new to animal nutritionists, their effects on mineral availability have been known to plant and industrial scientists for many years. Chelation is used in medicine as a means of helping to free the body of toxic cations, such as lead, and it is possible that they may be of major importance in the regulation of many of the reactions which we now take for granted, for example, the calcium and phosphorus requirement for deposition of bone. It remains for the nutritionist to learn which chelates are beneficial and which are harmful or toxic.

Practically all metals which form stable di- or polyvalent ions can be chelated. The most common are the alkaline earths (calcium, magnesium, etc.) and the transition metals (copper, nickel, zinc, cobalt, etc.). For all practical purposes the alkali metals (sodium, potassium, etc.) are unaffected. The pH of the system determines to a great extent which metals are chelated preferentially. Higher concentrations of the hydroxy ion will cause precipitation and metal hydroxides will react with the amphoteric metals to give various complex ions. In either instance, the metal chelate is destroyed or prevented from forming. Chelating products have low acute oral toxicity. In the concentrations used biologically, they are not irritating to the skin and eyes and, therefore, do not present handling problems.

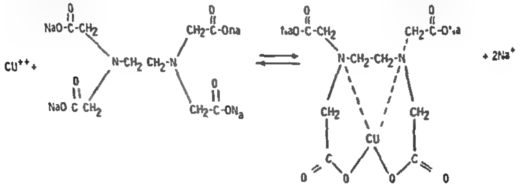


FIG. 23 3 REACTION OF COPPER METAL ION AND EDTA

Since the chelating agent is an organic chemical which surrounds metallic ions with multiple ring structures, it keeps the metal chemically inactive and holds it in solution. There are many present and promising applications in industry and nutrition. When used in solution, they inactivate practically any polyvalent metallic ions that they contact. They accomplish this by actually forming a new compound in which the metal ion becomes a member of a stable inner ring structure in the molecule so that no reversion or breakdown can occur. In nature, many compounds are attracted by a cation (an element with a deficiency of electrons) with which it can

share its electrons thereby forming a stable compound. Usually the compound thus formed is highly insoluble in water but nevertheless dissociates to a sufficient extent in the intestinal tract to allow absorption of the essential cations. This is usually brought about by hydrochloric acid from the proventriculus which tends to convert all of the cations temporarily into the chloride salts which allow a considerable degree of ionic dissociation. This results in good absorption from the intestinal tract.

The availability of zinc is an example of absorption as it is affected by chelation. Once the importance of zinc in the diet of the chick had been established, it was found that the zinc requirement was greater when a diet containing isolated soybean protein was fed than in one containing casein, gelatin or egg white. California researchers observed that EDTA, a chelating agent, markedly improved zinc absorption and reduced the amount necessary in the diet.

Organic chelates of certain mineral elements may be most important factors controlling utilization of these elements. If an element is chelated by a compound which will enhance absorption or release it in ionic form at the intestinal wall this may greatly improve absorption of the element. They may prevent conversion to an insoluble colloid in the intestine which would prevent absorption.

Chelates show exceptional high stability in solution. Many chelates are highly absorbable and prevent the metal ions from forming an insoluble metal complex. This type of chelate is called a "sequestering" agent. Chelates in biological systems may serve to transport and store metal ions. They may be used in metabolism or may interfere with utilization of the central cations.

As an example of the action of chelates in poultry nutrition, it was found that the availability of zinc for chicks fed a purified ration containing raw soybean protein is greatly enhanced by addition to the diet of EDTA. Phytic acid is a constituent of isolated soybean protein. The feeding of this isolated protein in some way was responsible for the unavailability of zinc for chickens and turkey poults. This growth depression could be corrected by the addition of zinc to the diet. This suggested that zinc phytate interaction decreases the biological availability of zinc. Phytic acid in the diet increases the fecal elimination of zinc about twofold. From in vitro studies it was found that isolated soybean protein can bind zinc. The addition of sodium phytate to isolated protein increased the amount of zinc which was to be bound. EDTA or citric acid effectively removed the zinc from the soybean protein and brought it in solution. The reason for the improvement of growth on a practical deficiency of zinc by the addition of a synthetic chelation agent is not clear. It might function by transporting the mineral to a site in the intestinal tract more favorable for absorption.

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Moldy Feeds

INTRODUCTION

Moldy grain should not be used in feed manufacture unless checked to be certain it is safe. The quickest way is to feed it to a few birds and see if it has any adverse effects which may range all the way from lack of palatability to death of the test animals. A reference group fed wholesome feed must be carried along for comparison with the test group. Only after a feeding test can any assurance be given that a questionable sample is safe for feed use.

NATURE OF MOLDS AND YEAST

Molds and yeasts belong in a part of the plant kingdom known as fungi (mycophyta). Molds are present and grow under a wide variety of conditions. Their toxins (mycotoxins) are markedly resistant to physical and chemical treatment. Turkey poults, ducklings, and pheasants are susceptible. Fortunately, chickens are not particularly susceptible to the toxins. Growth depression and histological changes in the liver are obtained. Pullets carried through normal egg production on toxic meal showed no evidence for carryover of the toxin into the eggs. As the relative humidity was increased in corn from 70 to 100%, the total mold count increased logarithmically, the internal mold infection increased sharply, and fat acidity increased sharply. The best single index of corn deterioration is the decrease in nonreducing sugar content. There is no difference in performance of broilers fed sample grain corn containing a significantly higher amount of molds than No. 1 corn, but the sample grade gives significantly less pigmentation.

AFLATOXINS

Molds can either be beneficial or injurious depending on their identity, environment, and/or conditions of use. Moldy cheese is good if it is roquefort; bad if it is creamed cheese. Molds can be beneficial when they produce antibiotics and harmful if they produce toxins. *Aspergillus flavus* toxins consist of four principal entities (aflatoxins B_1, B_2, G_1 and G_2). Aflatoxin B_1 is acutely toxic. Rations containing only 0.03 ppm of aflatoxin B_1 from peanut meal develop liver tumors over long feeding periods.

Fungi play an important role in livestock and poultry production. Peanuts (groundnuts) are not poisonous but under certain conditions fungi

gain access to and multiply on the crop. Over 10,000 turkeys died in Great Britain in 1960 from mycotoxins contained on peanuts. Microorganisms growing on grain are a cause for suspicion. Ergot on wheat is well-known. Scabby barley naturally infected with *Fusarium graminearium* is toxic to all species of animals. Aspergillosis, thrush, and favus result from toxic fungi. *A. flavus* elaborates aflatoxins. *A. fumigatus* acts primarily on the mouth, trachea, bronchi, and air sacs of the host. Increased respiration is followed by rising body temperature and diarrhea.

MYCOSES

Mycotic infections (mycosis) are invasions by pathogenic fungi of various tissues of a susceptible host. Mycotoxins are metabolites formed primarily by saprophytic fungi. In the first instance, the organism is the inciting agent; in the second, the preformed metabolite in the feed of an animal causes the trouble. The problem of toxic fungi appears to be associated more with management and environment than with feed per se. The toxic compounds are polycyclic, unsaturated lactones and are stable to heat. Supplementation of diets containing moldy meals with certain amino acids tends to counteract the toxic effect. Whether the mycotoxins affect the availability of the amino acids remains for future researchers to determine.

Molds are composed partly of thread-like tissues (hyphae) that grow at the tips. Behind the tips are active regions of older cells and behind these are vacuolated cells which have small cavities or spaces containing air or fluid. During some years, wet field conditions may exist during the latter part of the growing season and cause greater field infestation with fungal organisms in the developing corn plants. Field molds are of several types. One type, *Gibberella* or *Fusarium*, produces estrogenic substances. It is possible that these substances inhibit ovulation and egg production in the laying hen.

FEEDING MOLDY GRAIN

Should moldy corn be fed to poultry? As stated, most molds are not harmful in quantities as they sometimes occur in grains. Hence, most moldy grains can be fed without bad side effects but some molds are harmful and will affect animals. The only sure way to determine whether or not moldy feed is toxic is to try it. This does not mean feeding it to the entire flock. Trying it means feeding it to a few birds away from the others. See what happens during a two-week period. If the birds are normal after two weeks, the grain can probably be fed safely. It may be wise to dilute the moldy grain with an equal amount of sound grain when possible. The combination of a negative test on a few birds and the dilution of sound grains

should make it safe to use. If the moldy grains produce an adverse effect, such as reduced growth, lower egg production, and reduced feed consumption, dilute the amount of grain with sound grain to a point where toxicity is eliminated, or feed the moldy feed to a nonsensitive animal. Cattle are considerably less sensitive to molds than swine or poultry. If the test birds are killed by feeding the moldy grain, then the grain is not usable and should be destroyed because the toxin cannot be removed to make the grain safe. Sulfonamides and antibiotics have not proved effective against fungi. If fungi are not allowed to develop they will not contaminate the feed or infect the birds.

Field molds which invade grain when the plant develops in the field require at least 22 to 25% moisture. Normally these molds do not grow after harvest except in corn stored on the cob. Poisons formed by the molds in the field are not destroyed by heating or cleaning the grain, etc. They gradually are destroyed in stored seeds at moisture contents of 13 to 18%, and do not require free water to grow. They are mainly species of *Aspergillus* which do not invade seeds to any extent before harvest. Nearly all storage molds invade the germ of the seed. Germs of grains stored for a few years with a moisture content of 14 to 15% can be completely decayed. Such germ-damaged grain is referred to as "sick." Corn stored on a cob in piles and at high moisture content in cribs become decayed throughout the kernel. *Fusarium erium* and *Gibberella zia* complex are the principal cob-rotting molds. Corn that undergoes such spoilage is estrogenic and must be fed with caution to young breeding animals.

RED STREAKING OF CORN

Red streaking of corn was observed in the Midwest in 1963 and since in several other States and Canada. This condition is caused by a virus, and there is no apparent reduction in feeding value. When using a new supply of corn it is desirable to gradually replace the old supply rather then make an abrupt change. This applies particularly when molds have been observed prior to or after harvest and when using corn of unknown origin. The feeding value of questionable corn should be determined first on a few animals before mixing large quantities of feed. As a general recommendation, moldy corn should not be fed at more than 25% of the total feed. Corn unpalatable to younger stock in some cases can be used for older, growing, finishing stock. Combinations of moisture, temperature and other variables cause certain strains of common molds to produce mycotoxins. But there is enough knowledge at hand to reduce molds sharply. Numerous crops besides peanuts are susceptible to contamination by toxin-producing molds under certain conditions. Cottonseeds, soybeans, corn, rice and a number of small grains are farm commodities in which

mycotoxins have been found to occur naturally and have caused some trouble in isolated instances. While many molds have conspicuous growth, some are minute and detected only by laboratory methods. Actually, mold poisoning among livestock and poultry in the United States is relatively infrequent and sporadic.

SPECIE SUSCEPTIBILITY

There is a wide variation in tolerance to molds among various species of warm-blooded animals. Ducklings are extremely susceptible, and thus widely used as test animals to confirm the presence of aflatoxins. Sheep are relatively resistant. In diminishing order of susceptibility are: ducklings, turkeys, pheasants, pigs, cattle, and sheep. The young of most species are more susceptible than older animals. Aflatoxins are generally associated with low-grade or off-colored, damaged products. Modern farming operations keep mold levels to a minimum. However, harvesting at a high moisture content may damage the seeds in mechanical picking if the machinery is operated too fast or it is not properly adjusted. Mechanical drying has made the modern farmer more independent of the weather. High moisture is the single most important condition contributing to mold. Warm temperature also causes molding. Molds grow rapidly at temperatures of 60° to 100° F in combination with high relative humidity.

Mycotoxicosis is characterized clinically by depression, diarrhea, and paleness of the combs and wattles, followed by death. Necropsy findings include intramuscular hemorrhages, hemorrhages and congestion in the thymus, proventriculus, gizzard, heart, small intestine, ceca and spleen, as well as paleness and frequent enlargement of the liver and kidneys.

Maximum aflatoxin production occurs at 75° to 85° F. In one test, ⅓ of 500 varieties of molds tested were estrogenic, affecting the reproductive system. Grains stored in excess of 14½% moisture become moldy in storage. Filthy water not only contributes molds but harmful bacteria. Feeders should be kept clean. Ventilation should be adequate to prevent wet litter. Corn cob litter molds very easily. Litter should be kept dry. Grain, even though it has dead germs, can be of some feeding value if supplemental vitamin E is provided in the ration. Calcium propionate prevents the growth of molds and is approved by the Food and Drug Administration. Feeds containing cane molasses, fish solubles, and condensed fermentation products are susceptible to heating due to the water, not any other constituent. The use of mold inhibitors in mixed feeds may be economical during periods when feeds may have to be stored under conditions when heating is a major possibility.

CANDIDA ALBICANS MYCOSIS

Mycosis caused by *Candida albicans* invade and destroy the tissues of the upper digestive tract, particularly the crop and gizzard, and frequently causes formation of whitish ulcers in the crop and less frequently in the mouth, upper and lower esophagus, and proventriculus. Pendulus crops are observed in mycotic infection of turkeys and chickens. Excess gas caused by fermentation contributes to distension and ultimate distortion of the crop muscles and tissues. Mycosis may follow on the heels of avitaminosis due to decreased resistance. It could also complicate recovery from coccidiosis, bacterial, and viral disease. Outbreaks may be triggered by the prolonged use of antibacterial agents at high levels in the treatment of other diseases, such as Bluecomb in turkeys. This is due to alteration of the microbial balance in the digestive tract that allows fungi to become established in the lining of the digestive tract. Sloppy management, unsanitary conditions, overcrowding, poor ventilation, damp litter, hard to sanitize dirt floors, faulty water system, poor management and moldy feeds are factors which may contribute to mycosis which strikes at any time of the year.

Mold damaged grains, long regarded as acceptable for use in animal feeds, have recently come under suspicion in attempts to explain certain unidentified field conditions. Fungi proliferate in the field as well as in harvested grains and feedstuffs during storage. Damage from the fungi themselves, is more important in the field; during storage of grains mycotoxins are more important.

PREVIOUS OUTBREAKS OF MYCOSES

Most significant research on fungi has been conducted in the last decade, although the older literature reveals many instances where moldy feedstuffs caused toxic results, altered nutrient value, or reduced palatability.

In Georgia, during the 1940's, moldy corn caused the death of swine as a result of *Aspergillus flavus* and *Penicillium rubrum*. In the 1950's, a similar outbreak occurred in Alabama. In 1959, large numbers of turkey poults and ducklings died in England as a result of feeding contaminated peanut meal imported from Brazil. *Penicillium puberulum* was the cause of the problem. The toxin was carcinogenic when fed to rats.

The U.S. broiler industry has had sporadic occurrences over the years of hemorrhagic syndrome suspected to be due to *Alternaris, Aspergillus clovatus, A. flavus* and *Penicillium purpurogenum*.

Cattle, goats, horses, rabbits, guinea pigs, and other animals have also been reported to be susceptible to *Aspergillus chevaliere, A. flavus, Penicillium cyclopium, P. palitans, P. rubrum, Gibberella saubinettii,* and *G. zeae*.

During 1955, environmental conditions in the Midwest (Ohio, Indiana, Michigan, and Illinois) were favorable to mold growth before maturation of corn. Feed was refused and the following molds were predominant: *Gibberella roseum, Negrospora oryzae, Fusarium moniliforme, Diplodia zeae* and *Cephalosporium acremonium*. When the moldy feed was consumed, symptoms noted in swine included vomiting, estrogenic stimulation characterized by a swelling of the vulva, and rectal prolapse.

Molds in corn cause reduced fat, and increased water-soluble nitrogen, ash, calcium, and phosphorus in carcasses of rats. Some of the starch portion of the grain is destroyed. Fat acidity, reducing sugars, and total sugar content are reduced in wheat. Protein digestibility is lower. Lysine and arginine improves the growth rate of poults receiving moldy soybean meal, so the energy-amino acid relationship in the ration may be very important where moldy grains are used.

The hemorrhagic syndrome of poultry evolved in the last few decades during which time great changes were made in the formulation of feeds. Previously poultry feeds contained substantial amounts of alfalfa meal and wheat bran as well as a combination of grains. Modern high-energy rations contain antibiotics, growth stimulants, much more corn, and less alfalfa meal. These latter were introduced to reduce disease incidence and improve rate of growth.

As a sequel to these ration changes, diseases have recently developed which are still largely unexplained. Vitamin K added to feeds does not prevent hemorrhages. It helps to take care of clotting of blood only after hemorrhages occur. Antibiotics, sulfonamides, and growth promotion drugs control bacteria which are natural antagonists to some fungi. With bacteria limited, fungi multiply more abundantly within the tract of birds, feed, and environment. The promiscuous use of drugs (vitamin K antagonists) may cause over-growth of fungi which, in turn, weaken the capillary walls and cause hemorrhages.

Mycotoxicosis occurs in both acute and chronic forms in livestock and poultry from late fall through spring, when the natural moisture and temperature conditions are ideal for fungal growth. The acute form develops from continuous ingestation of sublethal amounts of toxin. In the chronic disease, there are pronounced changes in the cellular content of the blood.

Cultures from fungi isolated from suspected feeds fed to test animals frequently do not produce the symptoms noted in field cases of the disease. The substrate on which the mold is grown has an effect on toxin production. Differences in animal susceptibility to the toxins hamper investigation. Molds also affect palatability of feeds and sometimes animals refuse to eat until starvation forces them.

MOLD GROWTH REQUIREMENTS

Molds grow and thrive under damp conditions, not in water. Most molds do not invade the seeds or cereals before they are harvested; they do their damage during storage of the products. There are numerous factors which affect toxin formation—fungi strain differences, variations in the temperature from day to day, season to season and year to year, etc.

Fungi have their own unique optimum conditions necessary for toxin formation. When grown in pure culture, toxins form only under specific conditions and then they disappear. Fungi require relative humidity of about 80% and a temperature of 86° to 95°F. Toxins formed under natural conditions may vary considerably from that produced in culture in the laboratory.

To date, there is no simple method for the rapid detection and characterization of pathogenic fungi. Growth and survival of ducklings are used in evaluating toxicity, since this animal is more sensitive than most. Drawbacks of this test are that it is time-consuming and requires substantial amounts of toxin due to the length of the test. More recently a rabbit dermal test has been introduced. This requires less material and is rapid but has not been generally used, as yet.

Since all feed ingredients carry some mold spore contamination, careful inspection and rejection should be made to reduce the amount of damaged grains so as to prevent mass introduction of molds. Since molding is related to moisture levels in the grain and humidity around the grain, means of controlling moisture should be activated. Some compounds have fungicidal activity (8-hydroxyguinoline, parachlorophenyl ((trichloromethol)) thiosulfate, ethyl-1,3,5-trimethyl-4-nitroso-2-pyrrole-carboxylate, 2-bromo-5-nitro thiazole, and 2-chloro-5-nitropyridine), but are not permitted in livestock and poultry feeds by the U.S. Food and Drug Administration.

Since mold growth lowers nutrient value of feeds (break-down of fat and carbohydrates and lower protein digestibility), higher nutrient levels must be used in an attempt to offset the effect of molding.

Microbial contamination is not necessarily injurious and may on occasion have beneficial effects. For example, barleys grown in Western U.S. are harvested in a dry environment. Eastern barleys are gathered under conditions of greater humidity, are exposed to greater microbial populations, and contain more microbial enzymes (amylases) than the Western barleys. These enzymes help poultry in digesting the barley. Western barleys can be upgraded to the Eastern barley levels by treatment with water to stimulate fungal enzyme growth.

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Disease and Parasite Control

INTRODUCTION

Poultrymen believe that much disease results from contamination brought in by way of the feed, however there is little proof to document such belief. It is difficult to disassociate contamination of feed from that of litter, equipment, air, and water. Nevertheless, where nutrition and sanitation have been controlled as much as possible, results suggest that there may be some transmission of pathogenic agents by way of the feed under certain circumstances.

Some experiments have been made where feed was pasteurized by heating. This is not too promising for two reasons. First, heating reduces the value of certain nutrients such as the vitamins and proteins. Secondly, ground feed does not conduct heat very well and this insulating effect makes heat processing difficult to accomplish successfully.

Certain feed ingredients are processed in plants far removed from poultry production areas and at temperatures which would destroy any contamination. Such ingredients as dehydrated alfalfa meal, soybean meal, dried skimmilk or buttermilk, whey, brewers' dried yeast, distillers' dried solubles, animal fats, vegetable oils, molasses, salt, dicalcium phosphate, and defluorinated rock phosphate are prepared under sanitary conditions, and are protected after production by packaging in paper bags, tanks, or drums until mixed in the final feed. This procedure would protect against recontamination by pathogens. These items might represent 1/5 or more of the ration. The remainder consists primarily of grains, animal proteins, and micronutrients. Emphasis could be placed on making these free from pathogens.

Pathogenic agents consist of bacteria, viruses, fungi, parasites such as coccidia, and insects. A satisfactory preservation treatment would have to destroy these agents.

Biologicals are medicinal preparations made from living organisms and include vaccines, bacterins, serums, androgens, and toxoids. Antibiotics, which are also made from living organisms, are not considered biologicals. When bacteria, viruses, or a foreign protein enter a bird's body, they stimulate certain cells to make a product which ties up or destroys the foreign material if that same material enters the body again at a later date. The material that causes this reaction is called an antigen; the substance that the body produces to destroy it is called an antibody.

Condition of litter is a difficult problem to control. Frequent change and chemical treatment of litter, air-conditioning for increased ventilation, and the use of shavings or peanut hulls, instead of corn cobs and straw which are frequently exposed to contamination, may cut down infections. Veterinarians and poultry pathologists indicate that at least half of the disease incidence in poultry could be avoided if feed could be free of pathogens.

BATTERY SYSTEM

Producers are sometimes forced to grow poultry confined in densely populated cages or pens to reduce housing and labor costs. This practice increases the amount of contamination and the number of opportunities for ingesting contaminated material. For these reasons, it is expected that much good would be achieved if feed could be made free from pathogenic agents. One of the important advantages of the battery system is the reduction in diseases, especially those of parasitic origin.

Battery Fatigue

Diseases are less easily transmitted in batteries, but there are typical battery diseases which are often the result of restricted exercise of the birds and the impossibility to supply the diet with such ingredients as would normally be picked up out of the litter. While the background of battery fatigue is still unknown, symptoms occur in birds that have been in production for about 6 to 8 weeks, paralysis being among the most characteristic. Spontaneous fractures of the legs occur due to a decalcification of the bones. An increase in the calcium or vitamin D levels in the feed have no preventive value.

Dosages of phosphorus have some positive effect. Battery fatigue is limited to only 5 to 10% of the birds but it is still a serious economic handicap. The birds recover quickly if they are placed on the ground.

Other Conditions Associated with Batteries

About 20% of the mortality in battery cages is due to inflammation of the kidneys (nephritis). Wetness of droppings occur because it is believed the birds drink too much water due to boredom. However, a hormonal abnormality may possibly be involved. Fatty degeneration of the liver is associated with excessive feed intake, especially when the feed is rich in energy and poor in protein. Reduction in exercise may cause an energy surplus, fatty degeneration being the result. Fatty degeneration causes severe changes, especially in the liver. Again, the birds can be cured by placing them on the ground for some time or taking them out of production. Extra choline, methionine, vitamin E, and vitamin B_{12} have been proposed but have no beneficial effect. Well-balanced feeding with a high level of vitamin E every day is thought to prevent some of the prob-

lem. Batteries are the simplest, cheapest and most reliable prevention against coccidiosis because they break the life cycle of the parasite.

When birds are together in large scale confinement production, diseases spread rapidly and losses are sometimes devastating. New diseases and complications of old ones plague the industry. One disease that threatened to bring the developing poultry business to a grinding halt was coccidiosis. Because of a one-celled parasite, millions and millions of chicks died each year and 20% losses were not uncommon. Geneticists tried unsuccessfully to breed coccidiostat-resistant birds; management experts developed systems involving frequent changes of litter. Nutritionists tried to develop feeds that would protect the birds; milk products, iodized feeds, vinegar, sulfur in various forms were tried, but lacking basic knowledge of the disease were not successful. Coccidiosis still remains a major problem of the poultry industry.

COCCIDIOSIS

Coccidiosis once accounted for mortality rates as high as 40% but its impact has been greatly diminshed by effective coccidiostats. There are nine species of chicken coccidia, of which *E. tenella*, and *E. necatrix* cause the highest mortality. Seven species of coccidia have been identified in turkeys.

It was recognized early that there were two classifications of coccidiosis, fecal and intestinal. Identifying these was a first step in defining the disease process. The universities, experiment stations, and the drug industry began studying the disease. During years of study, parasitologists have identified about 20 species of coccidia in poultry, as well as in other animals. Coccidia look similar under the microscope but differ in size and economic importance. Pathologists can identify lesions caused by the organisms in specific areas of the bird's body. The ceca or blind pouches may be enlarged or filled with dry blood or cheesy exudate. Lesions may occur in the digestive tract causing damage in many areas, and also in the upper digestive tract of turkeys. Lesions may be found also in the duodenal loop and the upper part of the small intestine.

Infection Cycle

Coccidiosis is a disease that starts with the oocyst—the egg-like structure of the parasite. Moisture and warmth stimulate their development. Oocysts mature and become infective in the litter of infected hens. Once within the bird's digestive tract, the parasites multiply rapidly and invade and damage the tissue of the intestinal wall. On the 6th or 7th day after infection, many oocysts are passed into the litter. One coccidium is capable of producing 10,000 parasites during its lifetime. So, it is easy to see how a sick bird can start a cycle of infections that cause heavy losses

in the flock. Quail disease, often confused with coccidiosis in the field, causes bloody droppings and affects the cecum and lower intestines in a manner similar to coccidiosis. However, quail disease does not respond to antibiotics.

Scientists found that damage to the intestinal wall slows growth and lowers feed efficiency, even when the disease did not kill. They found that previous infections act like vaccinations. Protecting the bird against every infection is impossible. Chickens can develop immunity to 1 species of coccidiosis and still be susceptible to infection by 8 others. Thus, coccidiosis of chickens is in effect 9 diseases, not just 1. Community protection is sometimes just a brief duration, so control of the disease is attempted through programs of moderate exposure. Without drugs, treatment is impractical but knowledge of the mechanisms of immunity is essential to the successful use of drugs.

Some of the most devastating outbreaks of coccidiosis have occurred in clean, new houses. Starting in a coccidia-free environment with birds having had no exposure, there is no immunity to the various strains of the infective organisms. Oocysts may be carried on the feet of wild birds, caretaker's shoes, or equipment. Just a few oocysts can produce as many as 500,000 parasites. One infected bird may harbor as many as 65 million oocysts. Thus, infections can spread like an explosion.

Control of Coccidiosis.

When sulfonamides began to show remarkable control of infectious diseases in human medicine, poultry specialists were quick to try these new drugs on birds. Sulfaquinoxaline enabled poultrymen to reduce coccidiosis mortality effectively even when birds were grown under crowded conditions. Continuous feeding of sulfaquinoxaline made it possible for poultrymen to keep large flocks with less than 2% mortality attributed to coccidiosis. This was a dramatic achievement.

In 1954, a new drug, Nicarb, from Merck Laboratories, virtually eliminated coccidiosis as a serious problem in chickens. It was so effective that poultry raisers obtained high levels of performance, even though some began to neglect important management details. The poultry industry learned the importance of management details the hard way because neglect led to outbreaks of disease. Even the best of drugs cannot substitute for good management. Adequate feeding space, good equipment, proper litter, and close supervision of the flock are more essential today than ever before in spite of the increased effectiveness of modern drugs. While high temperature and humidity slow down the bird's feed intake, it speeds up the development of sporulated oocysts. So, when it is hot and humid, it is necessary to check to be sure the coccidiostat intake is up to required levels.

Different coccidiostats work in different ways. One type of action is metabolite antagonism, wherein the drug substitutes itself for the vitamin B_1 needed for coccidia to survive. Good management practices are: reduce moisture and keep humidity down, keep the house clean, prevent contamination from outside sources, feed a preventive level of satisfactory coccidiostat, and at the first sign of a disease call the serviceman. A drop in feed consumption, loose and bloody droppings, sickly appearance of birds, and coughing and sneezing are nature's warning signals.

COMPLETE DIAGNOSIS

When the poultryman suspects disease, several specimens that are typical of the whole flock should be sent to a diagnostic laboratory—not just a single bird. In many instances, help can be obtained from the highly specialized laboratories at the universities and drug manufacturers to back up the local diagnostic laboratory. Such laboratories have equipment and skills to make the differential diagnosis. A complete laboratory diagnosis of a disease problem is sometimes necessary for adequate protection of the investment in huge flocks of today. A complete diagnosis means more than an examination of a specimen of tissue and litter. Sometimes it is necessary for the poultry specialists to visit the flock and make first hand observations of environmental factors.

Modern poultry management depends more and more on science and less and less on intuition. Drugs are essential to the control of disease. They are profit tools when used judiciously along with good management practices. New drugs developed to meet the changing needs of the poultry industry are potent, versatile, and have a wide margin of safety. They help protect flocks by preventing oocyst buildup in birds and thus contribute to the total performance of the flock. More birds go to market, weight gains are better and the profit picture is improved when these drugs are used along with good management. The effectiveness of the partnership between science and agriculture is exemplified by the poultry industry in America, including two billion broilers per year, 100,000,000 turkeys, astronomical numbers of pigs and cattle, and production efficiency that is the envy of the world. Continued research gives assurance of continuing success.

DISEASES OF TURKEYS

Blue Comb

Blue Comb disease is a cause of concern to the turkey industry. It is more prevalent in areas which practice year-round turkey production. It is a disease of turkeys of all ages, breeds, and both sexes, and appears suddenly and affects almost 100% of the flock. Turkeys go off feed and

have reduced water intake. Body temperature falls 5 or 6°. They lose weight, become emaciated, and have loose watery droppings which contain mucous threads and urates. Heads and necks tend to become a dark blue color. Laying birds lose production with chalky egg shells. Usually flock mortality will average from 5 to 25%. The younger the poults, the higher the mortality. The course of the disease runs 10 to 14 days. Major losses lie in decreased feed conversion and weight losses, and increased litter, medication, and labor costs. Lower grades and yields at the processing plant add approximately 2c per lb to the cost of production in flocks experiencing a moderate case of the disease.

Method of Spreading Disease.—Turkeys recovered from a case of Blue Comb have immunity against a second attack, but continue to eliminate the infective agent in their droppings. Fecal contamination of the drinking water makes for very rapid spread of the disease. Chickens, pheasants, and sea gulls are not carriers of the agent. However, any free-flying birds which obtain food from turkey yards and immediately fly to a neighboring flock would be a mechanical carrier of infective fecal material. Canadian workers have identified the infective agent from the intestinal tracts of turkeys as a bacteria of the genus *Vibrio*. The lack of a convenient test for the presence of the infective agent is holding back control of the disease.

Control of Disease.—Antibiotics, feed additives, immune serum, drugs, and chemicals of all types have been used, but have been ineffective in preventing the disease. A strict sanitation and isolation program is recommended. A crude vaccine from suspensions of infected turkey intestinal tracts is promising but more work must be done with it.

INFECTION WITH PARASITES

Parasites damage the animal body by living on tissues and substances that feed these tissues. Infections develop gradually. In the long run, damage becomes so great that profitable management is impossible.

Parasites cause: (1) damage to the intestinal wall and thus impede absorption of nutrients; (2) loss of nutrients intended for the host; (3) occlusions to blood and lymphatic vessels; (4) wounds by which other pathogenic organisms enter the body; and (5) harmful substances to develop in the body. Once present, parasites multiply and are easily transmitted by footwear, clothing, car tires, and packing materials. To limit damage, hygienic methods, good management, specific control measures and identification of the disorder are needed.

One method of parasite prevention is good nutrition, a factor in the animal's general health. Certain substances, such as vitamin A, have a great effect on the resistance of the body against parasites because it has protective values for epithelial tissue. The mucous membrane of the

gastrointestinal tract secretes protective substances which attack infectious organisms and parasites. This function is disturbed if vitamin A is deficient, particularly in the case of coccidiosis in poultry.

The PPLO (pleuro-pneumonia-like-organism) situation in poultry flocks has reached a puzzling stage. Outbreaks still occur in many flocks. When PPLO occurs in previously free flocks, tremendous losses result since the birds have no opportunity to develop resistance to the infection. For control, checking pipped embryos for PPLO lesions on the thoracic air sacs, and the serology test are used. Chickens pick up PPLO infection from birds carrying an active infection, in a contaminated hatchery, from wild birds, or by other physical means. Antibodies can be detected in the blood ten days after infection begins.

Internal parasites in poultry are tremendously prolific—one female large round worm can lay as many as 5,000 eggs per day. Thus, a worm population explosion can take place in the intestines in a bird and a light infection in a few birds can develop quickly into a major problem throughout the flock. By the time they are detected, worms have already done damage. Effective worm control calls for action against several stages in the worms' development. Purge wormers expel large round worms and cecal worms but are ineffective against immature worms or capillaria worms. Continuous in-feed antibiotics, such as Hygro Mix, used at proper levels halts worm egg production, destroys mature worms, and prevents a large share of immature worms from reaching the egg-laying stage. It is effective against large round worms, cecal worms, and capillaria worms, and offers a means for controlling the worm population.

Avian Hysteria

Avian hysteria is a condition of complex causes affecting all strains of chickens. Suspected causes are insufficient protein intake, poor ventilation with dust or ammonia, insufficient floor space, irritation or poorly debeaked birds, and warm weather which decreases feed intake. It is common in high-producing birds with large egg size. Affected birds lose all normal social behavior and sense of direction, mill around, hide and fly in every direction, making unusual crying and squawking sounds. They go into a molt and egg production drops. Genetics may be involved. Attempts to reproduce the disease have failed. It is not contagious. Crowding plays some role in triggering the outbreak. Many drugs, feeds, and management practices have been tried with varying degrees of success. Increasing the protein level, adding cultured yeast or adding 100 gm of niacin per ton of feed has also been advocated. Tranquilizers have been used. Hysteria stems from malfunction or degeneration of the central nervous system, either the brain or spinal cord.

PESTICIDE CONTAMINATION

The spraying of poultry houses and poultry equipment in the presence of poultry leads to rapid storage of pesticide residues in poultry tissue and eggs. As much time as possible should be allowed after spraying before broilers or layers are housed. The outer layers of grain seeds retain the largest amount of pesticide residue. The greatest degree of contamination of animal products with farm-used insecticides and pesticides comes about through the feeding of forages. Grains and grain products are less implicated and commercial feeds the least. Much additional research must be done on the question of carryover of pesticide residues in the products so extensively used in commercial feeds—oilmeals, meat and cereal by-products, and distillers' and brewers' by-products.

Feed manufacturers should take precautions to prevent contaminated materials from entering the plant and should attempt to retain identification of ingredients and feed additives as they are delivered in order that any trouble which may develop may be traced to the ingredients. In the interest of the wholesome as well as economical supply of food of animal origin, the feed and poultry industries recognize the need to hold pesticide residues to a minimum. It subscribes to the policy of exercising all reasonable precautions but at the same time demands a realistic approach toward the establishment of safe tolerances for all feed products. Chlorinated hydrocarbons have been used widely for less than 20 yr and directed primarily toward the control of various insect pests. Feedstuffs lend themselves to contamination by insecticides through various means unless proper precautions are taken. The occurrence of these insecticides in feeds leads to their presence in foods of animal origin. Consequently, it is necessary to control the presence of insecticides in feeds.

Chlorinated Hydrocarbon Insecticides

When poultry ingest feeds contaminated with chlorinated hydrocarbon insecticides, the compounds deposit in the tissues and hence in meat products prepared from the animal. This is particularly true of meat high in fat, since this insecticide is fat-soluble and hence tends to become concentrated in fatty tissues. Some of the insecticides are not only retained in the fatty tissues but actually converted into more toxic forms before they are stored. This is true of Aldrin and Heptachlor. Nonfatty tissues contain very low concentrations of the chemical although they are not completely free from contamination. DDT appears in eggs even when relatively low levels of insecticides occur in the diet.

Feedstuffs become contaminated with chlorinated hydrocarbon insecticides in a number of different ways: absorption from the soil, application of the chemicals during growth, and use of water contaminated

with the compounds in the preparation of the feed. The insecticide is most persistent in sandy soils. Uptake and deposition from the soil has been demonstrated for numerous feed crops. Direct application of these chemicals to control insects is probably the greatest source of contamination.

Mode of Contamination

Alfalfa, wheat, and other major components of poultry feeds, including corn, oats, oilmeals, and meat meals may be contaminated. Bodies of water may become contaminated with insecticides through direct application for control of various pests or through run-off water which has picked up the chemicals from contaminated plants or soil. Probably DDT is the most widespread contaminant but appears at a maximum concentration of less than 1 ppm. A survey showed that more than 50% of the feeds tested contained BHC, Aldrin, DDT, Endrin, Chlordane, and Dieldrin. The average level of contamination was generally quite low, although individual feeds contained enough insecticide so that they might appear in animal products. Thus, the presence of insecticide residues in feedstuffs must be of concern to the feed and poultry industries, for these materials if consumed by animals are deposited in animal tissues or appear in animal products.

Feedstuffs may become contaminated from a variety of sources including the soil, spray, or dusting treatments. When insectidies are used properly the magnitude of contamination should be quite low. In Rachel Carson's controversial book, *Silent Spring*, there is discussed one side of this serious problem. The other is presented by competent scientists but probably less effectively to the general public. This position might be summarized as follows: The book is an emotional and not a scientific appraisal of the problem. The danger from insecticide residues from foods is grossly exaggerated. Instances where damage is claimed from pesticides result from improper use of the chemicals. Agricultural chemicals are necessary for growing food to feed the present world population and will become more essential as the world population increases. The book has virtue, nevertheless. It emphasizes that those who use agricultural chemicals should be aware of the problem and use reasonable care in using them. Excessive residues are undesirable and illegal. Label precautions, careful use levels, and proper withdrawal periods are designed to leave food products free from harmful residues. The Food and Drug Administration is charged with the responsibility that necessary care is used to keep our food supply safe, but keeping in mind that there is no such thing as absolute safety. Nearly everything we do involves a calculated risk.

Position of Pesticide Residue Committee

The Pesticide Residue Committee of the National Academy of Sciences, National Research Council, is cognizant of the advances that have been

made through discovery, manufacture, and application of new chemicals for the control of pests of all types and that their uses are necessary to the health, nutrition, and economy of the nation. The Committee believes that the valuable properties of these chemicals can be utilized without exposing people, domestic animals, fish, or wildlife to undue risk. They have recommended that the concept of "no residue" and "zero tolerance" as employed in the registration and regulation of pesticides are scientifically and administratively untenable and should be abandoned. They recommend an expanded research program on the persistence of pesticides in the total environment and on the toxicology, pharmacology, and biochemistry of pesticides that would improve the reliability and precision of animal studies and their relevance to man.

Poison-treated or Mercury-treated Seed Grains

The U.S. Food and Drug Administration prohibits the sale, storage, and use of poison-treated and mercury-treated seed grains. Such grains will be seized by the government and violators may face fine and imprisonment. One lone kernel of treated grain contaminates the entire lot. Destroy all leftover treated seeds. *Do not mix any* treated seed or grain with other feedstuffs.

Competition Between Man and Organisms

There is constant strife between man and many organisms for the same raw material. The battle of survival will be won by those who can take advantage of situations. These organisms are highly efficient competitors for things humans need and want. Although man has been successful so far, insects, plant diseases, nematodes, weeds, and rodents have not given up the fight. More than 3,000 species of insects, as many plant diseases and uncounted numbers of other competitors attack the things which humans need. Losses to these pests amount to between 8 and 15 billion dollars a year, a quarter of our annual production, in direct defiance of the best protective measures that we can throw against them. It is necessary to plant an extra 88 million acres for them to harvest and another 32 million acres to make up for postharvest losses. What would happen if all our pesticides were prohibited? Cereal, forage, and farm crops might be reduced from 10 to 25% and the quality of the products would go down. The same would be true of domestic animals and animal products.

The greatest concern over the use of pesticides has been the relationship between their use and human health, through exposure of people one way or another to the toxic material. As a result of some unfavorable publicity, the World Health Organization, the U.S. Public Health Service and the Food Protection Committee of the National Research Council concluded

that: (1) the use of pesticides is recommended consistent with the rules and regulations promulgated under existing laws; and (2) careless and unauthorized use of pesticidal chemicals might pose a potential hazard which would require further careful observations, although at the moment there is no cause for alarm. It is clear that wildlife may be subjected to hazards which are not problems to people or domestic animals.

Federal Laws *Controlling Pesticides*

Laws and regulations have been set up for the protection of human and animal food supplies. Two Federal laws control pesticides in interstate commerce and are designed to give protection to the public. They are the Federal Food, Drug, and Cosmetic Act as amended by the Miller bill, and Federal Insecticide, Fungicide, and Rodenticide bill. The first provides for pretesting and the establishment of safe tolerances before new material intended for use on food crops can be put on the market. The second provides that new materials shall not be registered for sale in interstate commerce until complete specifications have been filed and adequate data have been presented to establish its usefulness for the purposes claimed as well as its safety when used as prescribed. These two pieces of legislation are in the public interest and make it necessary for manufacturers to spend many hundreds of thousands of dollars before a new product can be marketed. In providing for the safety of the consuming public, safety factors from 10- to 100-fold have been built into recommendations. These controlling laws are there for a purpose even though some of the tolerances represent legal rather than scientific biological limitations. They are there to protect humans. More than 200 basic chemicals are now produced and offered for sale on our farms.

The Miller bill passed in 1954 and is now known as the Pesticide Amendment of the Food, Drug, and Cosmetic Act. It gives the Food and Drug Administration authority to establish and enforce tolerances for pesticides and chemicals in raw agricultural products. Since 1954, more than 2,000 such tolerances or exceptions from the tolerances have been established for a wide variety of pesticide chemicals. Special attention has been given to the chlorinated hydrocarbon group of chemicals, among which DDT and its homologues are by far the most widely used. Because they have the unhappy faculty of being transmitted through the biological system of the animal and stored in the fatty tissue, feeds treated with these pesticides clearly are an important source of residue. Feeds containing pesticide residues cause some transfer of these to the tissues of turkeys and hens, especially in the fat. Dusting birds and spraying poultry houses also lead to transfer of chlorinated hydrocarbons to the flesh of poultry. Keeping down the amount of pesticides used and allowing as much time after spraying

as possible before housing the birds are helpful in reducing transfer of pesticides.

Pesticide Transfer to Eggs

Hens exposed to pesticide sprays will in a short time transfer pesticides to the egg. DDT concentrates in the yolk of the egg and to a much lesser degree in the albumen. The selection of the right pesticide for a given purpose, used in the minimum amount on a carefully chosen carrier, and applied in such a manner as to minimize uptake of pesticide will go far toward solving the pesticide residue problem. If birds have been exposed to high pesticide residue levels, they should be removed to uncontaminated feedlots as soon as possible, so that they eliminate the ingested residue before marketing time.

CONTROL OF FLIES

A female fly lays up to 3,000 eggs in her 3- to 20-day life in poultry manure or any moist organic material. Offspring grow in about seven days to the egg, larvae, pupal, and adult stages. Control flies by: (1) removing droppings every seven days to break the life cycle (effective but costly); (2) provide ventilation to dry and cone droppings; (3) prevent rain and drinking water from spilling into dropping pits; (4) apply dry sawdust to wet pit areas; (5) clean and adjust waterers regularly; (6) water 30 min every 2 hr; (7) use mash feed, not crumbles; (8) reduce salt in feed during hot weather; (9) remove dead birds and other animals; (10) mow grass and weeds near houses; (11) store manure under water or use lagoons; (12) darken houses to prevent larval growth; and (13) screen buildings. Fly control requires, in addition, chemical sprays or baits, i.e., Diazininon, Cygaon, Vapolna, and Ronnell. Don't use lindane, DDT, and other chlorinated hydrocarbons that leave residues in eggs and meat.

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MEDICATED FEEDS

State and Federal agencies standards promote honesty and fair-dealing. There are several kinds: (1) "identity" which tells what a feed is or what a poultryman can expect to receive when he selects the feed by its usual name; (2) "quality" which sets minimum standards and specifications for color, odor, flavor, nutritional value, cleanliness, texture, tenderness, and freedom from defects; (3) "fill" is how full the container must be to avoid deception and to meet the net weight or volume claim stated on the package; (4) "microbial growth" which may produce food poisoning.

Factors Affecting Growth of Microorganisms

Factors that influence the growth of microorganisms in feeds are available nutrients, moisture, temperature, and oxygen. Most feedstuffs con-

tain the nutrients to support growth of microorganisms. A low moisture content retards growth, as in the case of dried feed. Temperature is important since microbial growth is fairly rapid between 50° and 70° F, and exceptionally rapid from 70° to 120° F. Bacterial growth is greatly reduced at temperatures below 40° F and above 140° F.

Growth of hazardous bacteria can be prevented by storage at less than 40° F and by dehydration to less than 25% moisture. The addition of salt and other certain chemical additives and a pH below 4.2 help preservation. Salmonellosis, streptococcal poisoning, dysentery, typhoid fever, and infectious hepatitis can be introduced through food-borne infection. There are two ways by which bacteria cause illness. First, the bacteria in the food ingested localize and grow in tissue and in the host. The second type of food poisoning is by food-borne intoxication. In this case, organisms multiply and liberate a toxin in the food. The toxin causes the illness when the food is consumed. *Staphylococcus aureus* and *Clostridium botulinum* may produce food posioning toxins.

Every person involved in the manufacture and use of medicated feeds owes it to himself and his company to become acquainted with U.S. Food and Drug Administration requirements in the use of drugs and must comply to the best of his ability in spirit and practice.

Food and Drug Insepction

Compliance is achieved by the inspection of mills. Official sampling of animal tissues at processing plants for excessive residues of drugs is done. It is not difficult to comply if sound business practices are followed in all operations and the company is obviously doing its best to follow the rules.

All drug substances (including antibiotics) and additives are listed by the Food and Drug Administration. Those which are "old" drugs do not require an N.D.A. (new drug application); those which are "new" drugs require either an N.D.A. or an Antibiotic Form 10. Receiving records, perpetual inventory records, and mix sheets are filed which demonstrate that each additive is being properly used. Report on each drug shows name of substance, amount, manufacturer's lot number, your lot number (if any), and receiving date. Drugs are stored separately in a locked room under supervision of a responsible person and properly labeled. Materials from broken or open bags are stored in covered drums with the appropriate label on the side of each drum. Spilled material is cleaned up immediately. A perpetual inventory card is supplied for each lot of drug, feed additive, and microingredient showing lot number and each withdrawal, and are checked against mixing sheets and physical inventory each day.

An accurate mixing sheet is provided for each feed, preferably showing lot number for each drug substance in each mix. Personnel trained to handle drug substances and microingredients accurately and safely are supplied with appropriate safety equipment.

Mixing of Drugs

Mixing procedures are clearly written out. The addition of each ingredient is checked before charging the mixer to assure that it is the correct one, in the right amount, and that it is put in the mixer or mixing line. Drug substances, micronutrients, and other small quantity items are added when the mixer is partially (not over ¾) charged, or in such manner on a continuous operation as to assure adequate dispersion. Mixing time after fully charging the mixer is controlled to assure complete mixing. Adequate evidence is available showing that mixing times and methods are adequate for different types of mixes in order to establish minimum and maximum mixing times and procedures.

Mixing and conveying equipment is grounded to avoid electrostatic charges. Equipment is designed to avoid contamination of feeds from medicated feeds. This includes mixers, conveyors, bins, bulk tanks, bulk trucks, and used bags. Equipment is cleaned or flushed out with a common ingredient after each run of medicated feed or delivery of medicated feed. Such cleanout material is set aside in labeled containers for use as an ingredient in the next run of feed containing the same drug substance and ingredients.

Food and Drug Clearance

In order to be mentioned in the drug additive compendium, full Food and Drug Administration clearance must be had so that it is legal and claims can be made on a feed tag. Even though the drug company has this number, the feed manufacturer has to get his own new drug application providing it is classified as a new drug. It is necessary to write to the drug company and ask if they can refer to the new drug application number.

The following example summarizes what needs to be done. There are several new coccidiostats. A coccidiostat may be in use, but it is desired to use it at low levels along with an antibiotic. Even though this coccidiostat has been cleared, an antibiotic producer has to get clearance for this double combination. The Food and Drug Administration may insist on tests to show the effects of the additive on each part or component of the combination.

Coccidiostats are used in feeds if a reasonable degree of immunity has not already been established. No one coccidiostat remains effective for

very long because of drug resistance. Drugs are withdrawn from the feed for a period of time before meat birds are marketed.

Regulation of U.S. Drug Industry

The U.S. drug industry totals some thousand companies, yet its total sales are less than that of any one of a dozen other single companies in other fields. In recent years, there has been a virulent attack on the American pharmaceutical industry; their motives, profits, ethics, and even the quality of their products have been challenged. As a result, federal regulations have been put into effect which results in costs of millions of dollars to obtain rights for marketing a new drug.

It is costly to discover and develop new drugs. It appears that the drug industry has served as a convenient whipping boy. Through patents, the industry is given the right to a period of exclusive use of the drugs they discover through research. The drug industry must be given the opportunity to compete on the basis of merit and grow and prosper on the basis of performance. Of course, drug research could be centralized under the government. The free enterprise system has outperformed governmental research. The drug industry can look with pride on their performance over many years.

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Feed Formulation

PART 1 Introduction, Pelleting, Storage

In addition to being economically sound, a feed must result in the least cost per pound of meat or dozen of eggs. One must take into account a number of factors: strain of bird, environment, management, disease control, and choice of feed ingredients. Rations formulated strictly by the computer have not met with success at times because a nutritionist has not evaluated closely the derived formula to be sure that consideration was given to the many things that influence formulation. Many good feeds have been produced by manual calculation.

Feed formulators develop diets that are most economical by taking advantage of the various feed ingredients available at economical prices at various times of the year. It is self-evident, therefore, that feeds will differ in composition from time to time. Feed conversion, by and large, is an indication of feed quality but not necessarily so. The cost of producing a dozen eggs or a pound of meat is the only true criterion for evaluating a ration. The physical form of the ration must be considered along with its nutrient composition. The density of a crumbled or pelleted ration may be such that the birds tend to overeat but grow faster in a shorter period of time. This results in improved feed utilization. Obviously, this is not the best for growing replacement pullets where one is attempting to restrict nutrient intake and delay sexual maturity in hot weather or when birds are in colony cages. Where feeding space is limited, performance may be improved by feeding crumbles. However, for most laying operations mash feed will result in more economical performance than crumbles. Excess feed will be converted into fat and production will decrease. More feed is required to maintain the heavier bird and the chances of developing fatty liver syndrome are increased. Feeds too coarse result in picking.

Since feed represents the largest part (55%) of the production costs of poultry meat and eggs, a diet must be not only nutritionally but economically sound if it is to result in least-cost per pound of meat or dozen eggs produced. Feed at the lowest price per pound is not synonymous with the lowest cost per pound of meat or per dozen eggs. A computer cannot replace the nutritionist. There will be differences in ration composition at various times of the year as feed manufacturers adjust formulas in order to

take advantage of the most economical feedstuffs available at that time. The physical form of the ration should be considered along with nutrient composition. Low energy feeds are ideal for starting chickens, broilers, turkeys, ducks, and geese, because there is less feed wastage and no picking over of rations. Dustiness is reduced and feed consumption increased. Density may be altered to the point that birds overeat on crumbles or pelleted feeds. Crumbles and pellets can have a detrimental effect for growing replacement pullets where one is attempting to restrict nutrient intake and thus reduce sexual maturity.

A "gritty" texture in poultry feeds is desired. Birds fed pellets consume their daily feed requirements in 1/5 the time that it takes birds fed mash. The resulting spare time is often spent picking or fighting. A certain level of protein is needed in the ration in order to meet the bird's daily requirement for amino acids. However, the bird requires protein over and above its need for these nutrients. Once essential amino acid levels are met, the remainder of amino acids is not nearly as critical. One must at the same time, however, consider the energy of the ration, since this is the main factor controlling feed intake. The intake of vitamins and minerals is similarly affected by dietary energy level. Regardless of the nutritional quality of the feed, maximum efficiency of production will not be achieved unless the producer also gives careful consideration to management, disease, and breeding.

GRAINS

Corn

Corn is the most economical cereal grain available in Midwest United States and is used more extensively than other grains in formulating diets. Corn stored for several years may be 4% or more higher in dry matter than the 85% generally considered to be present in the current corn crop. Barley and oats are somewhat lower in energy content than corn. They may be fed to advantage at times, particularly if they are home grown.

Wheat

Wheat is an excellent replacement for corn in poultry rations. The amount of energy and protein provided per pound and the cost per calorie of energy and per unit of protein, as well as the number of calories of metabolizable energy per pound are essentially the same for wheat and corn. On the average, the percentage of protein in corn is 9, and in wheat 12, but there are a number of factors besides protein content that must be considered. These factors include amino acid balance, stickiness of ground wheat due to the gluten content, and the desired color of egg yolks in market eggs. Wheat devoid of yellow pigment may produce an undesirable

yolk color which can be overcome by the use of xanthophyll sources such as alfalfa meal and corn gluten meal. Feeds containing high levels of finely ground wheat cause pasting of the beak, and subsequently necrosis.

Oats

Oats have always been considered inferior to corn in rations. Weight gains by males are increased as the proportion of oats in the ration increases, but weights of females and efficiency of feed utilization are not affected noticeably.

Rye

Because rye grows reasonably well on poor soils, it is generally economically superior to corn in poultry rations. However, the low cost cannot offset the poor performance exhibited by rye-fed birds, namely, poor growth, wet and sticky droppings, and damp litter. Like barley, rye contains a carbohydrate gum, a water-soluble hemicellulose having a pentosan as its common repeating unit with five carbon sugars, xylose, and probably arabinose as its primary base. Treatments and supplements previously found adequate for improving barley do not improve the effectiveness with rye because of the differences in the type of gum. In the mash form, rye diets cause the beaks of chicks to be stuck closed due to adherence of feeds.

The chicken broiler can tolerate up to 25% of the grain portion of the diet as rye. Litter conditions with 50% of the grain fraction in rye are wholly inadequate. The hydrophilic nature of the gum passed in the excrement inhibits a normal moisture loss to vaporization. The presence of pentosan gums in rye may be useful as a pellet binder. During steam pelleting, a partial solubilization of these viscous gums occur with the gluing and setting of the associated adjacent particles upon extrusion and drying.

Bran and Middlings

Bran is low in energy content and high in bulk or fiber. Wheat middlings are almost as high in energy content as oats and barley and considerably higher in protein. Pelleting mill feeds improves their feeding value 10 to 15%. They can often be used to good advantage in growing rations where it is important to restrict energy intake.

Corn Gluten Meal

Corn gluten meal is usually available in rather limited quantities, but may be used up to 5% to replace an equivalent amount of protein from soybean meal. Lysine is often the first limiting amino acid in diets low in protein content, such as finishing feeds.

FEED COMPOSITION TABLES

Several rations for different classes of poultry are presented and are meant to serve only as guides. The everchanging supply picture and the price differential from one area to another make it inappropriate to supply rations for every situation. Vitamin-mineral premixes come in various potencies and are used to supply requirements. If iodized salt has been used there is no need to include iodine in the trace mineral premix.

Tables of feed composition are the heart of feed formulation because most decisions are based on them. Their accuracy and reliability are of great importance to the nutritionist. The need for a feed analysis compilation that would be a reliable guide for feed formulation has been recognized by the National Research Council. NRC classifies feeds into groups which have similar properties to be considered in formulating feed mixtures. Each feed is assigned a reference number of identification. Classifications are dry forages, pasture, silages, energy feeds, protein supplements, minerals, vitamins, and additives. For each feed, data have been recorded on a special form which has been prepared for use with computers. Tables contain data for proximate principles, fatty acids, lignin, carbohydrate factions, energy, 16 minerals, all vitamins, all amino acids, and several miscellaneous nutrients, as well as some toxic compounds. A total of 199 possible constituents are compiled. A complete reliable feed composition table is of great importance for feed analysis and quality control work.

Tables of feed composition are essential to the poultry nutritionist in order to check the adequacy of poultry rations. Such tables should be used only after careful study of how the data were obtained, the number of analyses, type of analytical methods, and the source and preparation of the feed. Average values for each feed are valuable if they are used with understanding of their limitations.

Feed composition tables list the nutrient content of ingredients used in the formulas shown. Protein, fat, mineral, and vitamin values carry a slight margin of safety, while the crude fiber values are slightly in excess of what may normally be encountered. Vitamin, trace mineral, and amino acid values are average values derived from a number of sources. Provitamin A is well utilized by the chick at lower requirement levels, but it is not as efficient as vitamin A when measured by liver storage when fed at higher levels. It can be assumed that ⅔ of the average analysis in provitamin A is the vitamin A activity of feed ingredients such as alfalfa meal. Choline and betaine are considered together because betaine can replace the methyl donor function of choline. Particular attention should be paid to methionine and cystine since these are the first limiting amino acids in diets based on corn and soybean oilmeal.

It is impossible to present formulas here that will result in most econom-

TABLE 26.1A

NEW ENGLAND CONFERENCE
CHICKEN RATIONS(1)*

Ingredient		Starter	Grower**	Breeder 3.5–5 Lb	Breeder 5-8 Lb
Ground yellow corn (2,3)*		1248	1339	1290	1333
Wheat middlings		100	300	...	100
Yellow grease (16)		20	20	60	20
Soybean meal (dehulled)		394	203	283	182
Fishmeal, herring (65%) (4,5)		50	.	60	75
Meat and bone meal (50%) (5)		50	50	50	50
Alfalfa meal (17%) (100,000 A per lb)		50	50	50	50
Corn distillers' dr gr with sols		50	.	50	50
Dicalcium phosphate (6)		10	12	9	5
Ground limestone, low magnesium (7)		21	19	141	128
Iodized salt		7	7	7	7
Antibiotic supplement		(8)			...
Antioxidant		(9)	(9)	(9)	(9)
Coccidiostat		(10)	(10)	...	..
Manganese (gm) (11)		52	52	52	52
DL Methionine				0 4	...
Zinc (gm) (17)				16	16
Vitamin supplements (12)					
Vitamin A	(USP units)	1,000,000	1,000,000	4,000,000	4,000,000
Vitamin D_3	(ICU)	681,000	681,000	1,362,000	1,362,000
Vitamin B_{12}	(mg)	6	6	6	6
Choline chloride	(mg)	364,000	75,400	114,000	145,000
Riboflavin	(mg)	1500	1500	3000	3000
Calcium pantothenate	(mg)	3000	3000	6000	6000
Niacin	(mg)	10,000	10,000	20,000	20,000
	Totals (lb) (21)	2000	2000	2000 4	2000
Calculated Analysis (25)					
Metabolizable energy	Cal per lb	1350	1340	1350	1315
Protein	%	20 00	15.00	17.00	16.00
Lysine	%	1 02	0.63	0 85	0.77
Methionine	%	0 35	0.25	0 33	0.30
Methionine + cystine	%	0.65	0.48	0.59	0.55
Fat	%	4 57	4.71	6 42	4.82
Fiber	%	3 02	3 43	2.55	2.84
Calcium	%	0 90	0.81	3.00	2.72
Total phosphorus	%	0 62	0 63	0.55	0.55
Available phosphorus (13)	%	0.38	0.35	0.48	0.47
Vitamins (units or mg per lb)					
Vitamin A activity	USP units per lb	4444	4520	5992	6040
Vitamin D	ICU per lb	340	340	681	681
Riboflavin	mg	1.90	1.75	2.57	2.61
Pantothenic acid	mg	5.11	5 08	5.96	6 06
Choline	mg	700.00	400.00	500.00	500 00
Niacin	mg	19.16	22.01	20.98	23.62

*See footnotes at end of table.
**See footnote 14

TABLE 26.1B

CHICKEN RATIONS (1)*

Ingredient		Layer: Caged Birds 3.5–5 Lb	Layer: Caged Birds 5–7 Lb	Layer: Floor Birds 3.5–5 Lb	Layer: Floor Birds 5–7 Lb
Ground yellow corn (2, 3)*		1301	1315	1355	1313
Wheat middlings		...	100	...	133
Yellow grease (16)		50	20	40	20
Soybean meal (dehulled)		303	240	322	312
Fishmeal, herring (65%) (4, 5)		50	40	50	...
Meat and bone meal (50%) (5)		50	50	50	50
Alfalfa meal (17%) (100,000 A per lb)		25	25	25	25
DDGS or equivalent (1)**		50	50	...	...
Dicalcium phosphate (6)		10	8	4	4
Ground limestone, low magnesium (7)		154	145	147	136
Iodized salt		7	7	7	7
Antioxidant		(9)	(9)	(9)	(9)
Manganese (gm) (11)		52	52	52	52
DL Methionine		0.5	0.4	0.5	0.6
Zinc (gm) (17)		16	16	...	...
Vitamin supplements (12)					
Vitamin A	(USP units)	6,500,000	6,500,000	5,000,000	5,000,000
Vitamin D_3	(ICU)	1,362,000	1,362,000	1,362,000	1,362,000
Vitamin B_{12}	(mg)	6	6	6	6
Choline chloride	(mg)	317,000	154,000	172,000	217,000
Riboflavin	(mg)	2000	2000	2000	1000
Calcium pantothenate	(mg)	4000	4000	2500	2000
Niacin	(mg)	20,000	20,000	20,000	20,000
Totals (lb) (21)		2000.5	2000.4	2000.5	2000.6
Calculated Analysis (25)					
Metabolizable energy	Cal. per lb.	1340	1302	1350	1300
Protein	%	17.00	16.00	17.00	16.00
Lysine	%	0.85	0.75	0.87	0.74
Methionine	%	0.33	0.31	0.33	0.29
Methionine + cystine	%	0.59	0.55	0.59	0.54
Fat	%	5.90	4.59	5.36	4.27
Fiber	%	2.25	2.56	2.16	2.59
Calcium	%	3.20	3.00	3.00	2.75
Total phosphorus	%	0.55	0.55	0.50	0.50
Available phosphorus (13)	%	0.48	0.47	0.43	0.41
Vitamins (units or mg per lb)					
Vitamin A activity	USP units per lb	6004	6020	5288	5240
Vitamin D	ICU per lb	681	681	681	681
Riboflavin	mg	1.98	1.98	1.92	1.38
Pantothenic acid	mg	4.81	4.96	4.05	4.10
Choline	mg	600.00	500.00	500.00	500.00
Niacin	mg	20.69	22.95	20.14	22.63

*( )See footnotes
**Corn distillers dried grains with solubles.

TABLE 26.1C

BROILER RATIONS (1)*

Ingredient		Starter (18)	Finisher (18)
Ground yellow corn (2,3)*		1098	1200
Yellow grease (16)		80	100
Soybean meal (dehulled)		540	385
Corn gluten meal (41%)		100	120
Fishmeal, herring (65%) (4,5)		110	100
Alfalfa meal (20%) (200,000 A per lb)		25	50
Dicalcium phosphate (6)		19	19
Ground limestone, low magnesium (7)		21	19
Iodized salt		7	7
Antibiotic supplement		(8)	(8)
Antioxidant		(9)	(9)
Coccidiostat		(10)	(10)
Organic arsenical supplement (19)		0.1	0.1
Manganese (gm) (15)		75	75
Vitamin supplements (12)			
Vitamin A	(USP units)	1,816,000	1,816,000
Vitamin D_3	(ICU)	681,000	681,000
Vitamin K (20)	(mg)	1000	1000
Vitamin B_{12}	(mg)	12	12
Choline chloride	(mg)	454,000	390,000
Riboflavin	(mg)	3000	3000
Calcium pantothenate	(mg)	5000	5000
Niacin	(mg)	20,000	20,000
	Totals (lb) (21)	2000.1	2000.1

Calculated Analysis (25)

		Starter	Finisher
Metabolizable energy	Cal per lb	1440	1480
Protein	%	24.00	21.00
Lysine	%	1.33	1.08
Methionine	%	0.45	0.41
Methionine + cystine	%	0.81	0.73
Fat	%	7.07	8.18
Fiber	%	2.16	2.31
Calcium	%	0.85	0.80
Total phosphorus	%	0.63	0.59
Available phosphorus (13)	%	0.40	0.38
Vitamins (units or mg per lb)			
Vitamin A activity	USP units per lb	4004	5490
Vitamin D	ICU per lb	340	340
Riboflavin	mg	2.60	2.64
Pantothenic acid	mg	6.13	5.99
Choline	mg	800.00	700.00
Niacin	mg	21.81	21.46
Xanthophyll	mg	10.35	13.39

*( ) See footnotes.
** Corn distillers dried grains with solubles.

TABLE 26.1D

TURKEY RATIONS (1)*

Ingredient		Starter (0–8 Wk)	Grower (8–16 Wk)	Finisher (16-Mkt)	Breeder
				(22)	
Ground yellow corn (2,3)*		875	1160	1493	1195
Wheat middlings		100	50	...	250
Yellow grease		40	50	50	20
Soybean meal (dehulled)		660	555	330	162
Fishmeal, herring (65%) (4,5)		115	...	...	100
Meat and bone meal (50%) (5)		100	50	50	50
Alfalfa meal (17%) (100,000 A per lb)		25	25	25	60
DDGS or equivalent (1)**		50	50	...	50
Dicalcium phosphate (6)		17	35	25	13
Ground limestone, low magnesium (7)		13	15	17	90
Iodized salt		5	10	10	10
Antibiotic supplement		(8)	...	...	...
Coccidiostat		(10)	(10)	...	...
DL Methionine		0.1	...	...	...
Ethoxyquin		0.25	0.25	0.25	0.25
Manganese (gm) (23)		30	30	30	30
Zinc (gm) (24)		30	30	30	30
Vitamin supplements (12)***					
Vitamin A	(USP units)	7,491,000	7,491,000	7,264,000	4,086,000
Vitamin D_3	(ICU)	1,700,000	1,700,000	1,700,000	1,700,000
Vitamin E	(IU)	10,000	5000	...	30,000
Vitamin B_{12}	(mg)	6	6	6	6
Choline chloride	(mg)	585,000	320,000	420,000	370,000
Riboflavin	(mg)	4000	5000	5000	5000
Calcium pantothenate	(mg)	4500	4500	6000	10,000
Niacin	(mg)	42,000	46,000	48,000	50,000
Vitamin E	(IU)	10,000	10,000	10,000	50,000
Totals (lb) (21)		2,000.35	2,000.25	2,000.25	2,000.25

Calculated Analysis (25)		Starter	Grower	Finisher	Breeder
Metabolizable energy	Cal per lb	1310	1360	1440	1285
Protein	%	28.00	21.32	16.18	17.00
Lysine	%	1.64	1.10	0.75	0.85
Methionine	%	0.48	0.34	0.27	0.33
Methionine + cystine	%	0.88	0.66	0.53	0.58
Fat	%	5.43	5.53	5.82	5.02
Fiber	%	2.73	2.60	2.29	3.38
Calcium	%	1.20	1.01	0.90	2.20
Total phosphorus	%	0.91	0.80	0.66	0.70
Available phosphorus (13)	%	0.65	0.55	0.45	0.61
Vitamins (units or mg per lb)					
Vitamin A activity	USP units per lb	6016	6340	6576	6427
Vitamin D	ICU per lb	850	850	850	850
Riboflavin	mg	3.28	3.51	3.38	3.72
Pantothenic acid	mg	6.31	5.82	5.87	8 52
Choline	mg	1000	700	600	650
Niacin	mg	36.82	35.16	33.82	42.70

*See footnotes

**Corn distillers dried grains with solubles.

***Biotin and folacin may be required under certain conditions. If desired, they may be added at the rate of 100 mg of biotin and 1000 mg of folacin per ton of feed.

TABLE 26.1E

VALUES USED TO DETERMINE THE ANALYSIS OF THE NEW ENGLAND COLLEGE CONFERENCE POULTRY RATIONS

Ingredient	M.E. Cal per Lb	% Prot.	% Fat	% Fiber	% Ca	% P	Vit. A IU per Lb	Xanthophyll Mg per Lb
Alfalfa meal (20%)	640	20.0	2.6	17.0	1.90	0.22	150,000	150
Alfalfa meal (17%)	500	17.0	2.5	26.0	1.40	0.21	100,000	120
Barley, ground	1190	11.0	2.1	6.0	0.07	0.36	...	...
Bone meal, steamed	450	6.5	0.6	2.6	31.30	14.50	...	...
Corn dry steepwater concentrate	1170	31.0	3.0	...	...	...	...	...
Corn, yellow, ground	1530	8.9	4.0	2.0	0.02	0.27	2270	11
Corn DDG with solubles	1050	28.0	8.0	7.0	0.19	0.35	1100	...
Corn distillers' dried solubles	1250	27.0	5.0	2.0	0.35	1.55	...	...
Corn ferm. solubles, dried extract	980	23.4	0.25	0.2	0.07	1.55	...	...
Corn gluten feed (yellow)	650	21.0	1.0	10.0	0.30	0.70	1000	30
Corn gluten meal (41%)	1480	41.0	2.0	3.0	0.07	0.37	12,000	60
Corn gluten meal (60%)	1580	60.0	2.7	2.0	0.18	0.39	20,600	160
Dicalcium phosphate	...	...	...	...	23.00	18.50	...	...
Fat								
Animal tallow, feed grade	3130	...	97.0	...	...	...	...	...
Fish oil	3490	...	95.0	...	...	...	...	...
Hydrolized animal and vegetable fat	3400	...	99.0	...	...	...	...	...
Poultry oil	3720	...	98.0	...	...	...	...	...
Yellow grease	3400	...	99.0	...	...	...	...	...
Fishmeal								
Canadian herring, 72%	1450	72.0	9.0	0.5	2.40	2.20	...	...
Maine herring, 65% (10% fat)	1420	65.0	10.0	0.5	3.00	2.30	...	...
Atlantic menhaden + 40% solubles	1330	62.0	9.0	0.5	5.50	3.00	...	...
Atlantic menhaden (58–65% protein)	1240	60.0	9.0	1.0	6.20	3.60	...	...
Peruvian	1200	65.0	4.0	1.0	3.80	2.50	...	...
Fish solubles, condensed	575	31.5	4.6	0.5	0.15	0.63	...	...
Grain sorghums, Milo	1500	10.5	3.0	2.5	0.04	0.32	...	...
Hominy feed (yellow)	1370	10.6	5.8	5.1	0.08	0.52	1600	...
Hydrolyzed poultry feathers	1160	87.0	5.0	1.4	0.22	0.77	...	...
Limestone, ground, high calcium	...	...	...	...	38.00	...	...	...
Limestone, ground, low magnesium	...	...	...	...	35.00	...	...	...
Meat and bone meal	900	50.0	10.0	2.5	10.00	5.00	...	...
Molasses, cane	890	3.0	...	...	0.65	0.08	...	...
Oats, ground	1170	11.0	4.5	11.0	0.10	0.36	...	...
Oyster shells, ground	...	...	...	...	38.00	...	...	...
Peanut meal	1200	44.0	6.1	11.8	0.17	0.56	...	...
Poultry by-product meal	1260	55.0	12.0	2.5	3.00	1.35	...	...
Sesame meal	820	42.0	7.0	6.5	2.00	1.30	...	...
Soybean meal (dehulled)	1120	49.0	0.5	2.5	0.20	0.60	...	...
Soybean meal (44% protein)	1020	44.0	0.5	5.2	0.30	0.60	...	...
Wheat, ground	1410	12.0	1.9	2.4	0.04	0.39	...	...
Wheat, bran	510	15.6	4.2	9.0	0.11	1.21	...	...
Wheat middlings	890	16.0	4.5	7.5	0.08	0.93	...	...
Whey, dried	860	12.5	0.7	0.3	0.85	0.70	...	...
Yeast, dried	880	45.0	3.0	1.4	1.30	1.25	...	...

[1] Wherever substitutions are made in the rations, the total nutrient content should be adjusted to meet established requirements.

[2] Two to four hundred pounds of coarsely ground wheat or yellow hominy may be used to replace an equal amount of corn. If wheat is used, add 200 000 IU of vitamin A for each 100 lb of corn removed.

[3] There is usually some loss of provitamin A activity in corn and alfalfa meal during storage. If stored ingredients are used, it may be advisable to increase the added vitamin A level of the ration by 1 000 or 2,000 IU per lb. This can be accomplished by increasing the recommended supplement by 2,000,000 or 4 000,000 IU per ton of feed.

[4] If a high salt fish meal is used, omit the added salt equal to that supplied by the fishmeal.

[5] Poultry by product meal may be substituted for all of the meat and bone scrap and up to 50% of the fishmeal. Correct for calcium and phosphorus loss due to substitution of poultry by product meal.

[6] Based on an 18.5% phosphorus product. Steamed bone meal or defluorinated rock phosphate may replace the dicalcium phosphate on a phosphorus basis.

[7] Based on 35% calcium limestone.

[8] An antibiotic may be used in these rations at the level recommended by the manufacturer.

[9] 1,2-dihydro-6-ethoxy-2,2,4-trimethylquinoline (ethoxyquin) or butylated hydroxy toluene (BHT) are antioxidants used in the chick starter and broiler ration and ethoxyquin in the breeder ration at the 0.0125% level to help prevent the appearance of encephalomalacia (crazy chick disease), and to help prevent the destruction of the fat-soluble vitamins. If desired, either may also be added at the 0.0125% level (¼ lb per ton) to the other rations.

[10] A coccidiosis-controlling drug may be used in these rations at the level recommended by the manufacturer.

[11] This amount of manganese will be furnished by 0.5 lb of manganese sulfate or 0.21 lb manganous oxide (70% feeding grades). An equivalent amount of manganese may be added from other acceptable sources.

[12] Caution should be used when high potency vitamin mixes are involved. It is recommended that 10 lb be the minimum amount of any item added to a ton of feed to insure proper mixing. Thus, high potency vitamin, mineral, or drug

TABLE 26.2

TYPICAL RATIONS AROUND THE WORLD

Ingredient	Israel	Singapore	Philippines	Thailand	Bolivia	Colombia	Costa Rica	Mexico	Paraguay	Peru	Uruguay	Queensland	Hawaii
Corn	35.0	43.0	45.0	7.0	45.0	73.0	25.0	69.3	45.0	18.0	40.0	30.0	...
Oats, barley	...	...	...	...	...	...	...	...	...	...	20.0	...	...
Wheat, millet	...	...	...	...	...	...	...	...	...	...	...	...	...
Sorghum	25.7	...	...	...	20.0	...	30.0	...	...	...	3.0	24.0	...
Rice	...	...	...	8.0	...	...	...	...	...	...	...	...	...
Fat	1.0	20.0	...	...	...	...	...	...	...	...	...	...	...
Bran, midds	...	5.0	20.0	57.0	14.0	...	15.0	7.5	35.0	30.0	10.0	10.0	...
Gr. feeds, dr. alfalfa	5.0	...	5.0	..	5.0	3.0	...	3.0	3.4	5.0	...	3.5	30.0
Molasses	...	...	...	..	...	...	3.0	...	...	...	...	...	30.0
Meat scrap, blood meal and bone	...	6.0	...	...	3.0	3.0	...	2.0	7.0	...	7.0	30.0	22.5
Fishmeal	2.0	10.0	20.0	7.0	4.0	...	...	2.5	...	8.0	...	...	5.0
Skimmilk, yeast	...	...	...	...	...	...	...	...	...	...	...	...	...
Veg. prot. meal	20.0	6.0	11.0	9.5	3.0	9.0	16.0	5.0	10.0	...	10.0	...	12.5
Dicalphos. or bone	1.5	1.5	...	...	3.5	0.5	...	2.5	...	5.0	1.5	...	...
Oyster shell	9.5	8.0	2.0	2.0	...	...	5.0	4.2	5.0	5.0	4.0	2.0	...
Salt	0.3	0.2	...	1.0	0.5	0.5	...	0.5	0.5	0.5	1.0	0.5	...
Vit., tr. min.	...	...	2.0	...	...	...	...	...	0.1	1.0	...	...	...
Grit	...	...	...	...	2.0	...	...	...	...	...	...	...	...

TABLE 26.2 (*Continued*)

Ingredient	*Congo*	Da-*honey*	Ghana	Kenya	Mo-rocco	Ibadan	W. Nigeria	Sudan	Tan-zania	Sahel	Burma	Cam-bodia	Ceylon	Alla-habad
Corn	40.0	29.5	49.0	27.0	13.0	67.0	65.6	35.0	36.0	26.0	20.0	29.5	...	36.0
Oats, barley	...	...	...	13.0	46.0	...	...	...	...	30.0	...	...	...	...
Wheat, millet	20.0	...	...	...	...	...	...	...	...	10.0	...	...	...	12.0
Sorghum	...	35.0	...	...	...	...	...	34.0	6.0	...	...	...	42.0	...
Rice	10.0	...	...	...	...	...	...	...	3.0	...	19.0	20.0	...	...
Fat	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bran, midds	...	...	20.0	20.0	26.0	7.0	4.0	...	23.5	14.0	20.5	15.0	19.5	12.0
Gr. feeds, dr. alfalfa	7.0	3.0	3.0	8.0	4.0	...	3.5	...	4.0	5.0	...	3.5	2.0	...
Molasses	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Meat scrap, blood meal and bone	4.0	...	11.0	20.0	4.5	5.0	1.0	10.0	19.5	...	12.5	...	...	...
Fishmeal	3.0	3.5	11.0	5.0	...	...	2.0	...	...	8.0	...	15.0	8.5	5.0
Skimmilk, yeast	...	5.0	...	...	...	...	...	...	...	...	...	...	...	...
Veg. prot. meal	12.0	15.0	...	4.0	...	17.0	15.0	15.0	4.0	7.0	22.0	15.0	21.5	30.0
Dicalphos. or bone	0.5	1.4	3.0	...	3.5	2.0	2.5	1.0	2.0	...	1.5	...	...	...
Oyster shell	3.0	7.0	3.0	3.0	3.0	1.0	6.0	1.0	...	1.0	1.5	2.0	...	2.0
Salt	0.5	0.3	...	...	...	1.0	0.4	0.5	0.5	1.0	0.5	...	0.5	...
Vit., tr. min.	...	0.3	...	...	...	...	...	0.5	0.5	2.0	2.5	...	...	3.0
Grit	...	...	...	...	...	0.5	...	...	...	...	...	...	6.5	...

ical rations under all conditions and for various times of the year. Typical rations recommended by the New England Conference are presented. Obviously, formulas must be altered to meet various situations as they arise throughout the world. However, the basic principles of nutrition must be rigidly adhered to if satisfactory practical rations are to result.

Unidentified growth factor supplements such as dried whey, dried yeast, and distillers' dried solubles, dried buttermilk and dried skimmilk are carriers of UGF. Response to these products is somewhat variable and sometimes not sufficient to justify their cost.

Fifty percent soybean meal is lower in fiber and higher in protein than the 44% product and is, therefore, used to advantage in high energy diets. Soybean meal is slightly deficient only in methionine and is by far the most important protein supplement used in poultry feeds.

The value of feeds is based on their nutrient content. It is first necessary to know their chemical content and physical characteristics for each type of diet. Secondly, the ingredients necessary to contribute these characteristics are chosen on the basis of economics. The relative value of feed ingredients is based on available energy, crude protein, and other critical nutrients. University of Maryland workers have based evaluation of feed ingredients on the prices of corn and soybean meal, since these feedstuffs constitute the major source of energy and protein in poultry rations. The method consists of determining the market value of the critical nutrients in corn and soybean meal, namely phosphorus, calcium, vitamin A activity, riboflavin, niacin, pantothenic acid, and choline equivalents. Thus, the value of metabolizable energy and a pound of protein supplied by the two basic ingredients are obtained. By knowing the value of critical nutrients in other feedstuffs, one can determine the value of each ingredient in relation to the values of corn and soybean meal. By using current values for these nutrients, it was determined that corn contains 4.98 cents worth of these nutrients per 100 lb, and soybean meal contains 19.57 cents worth of critical nutrients other than protein and energy per 100 lb. The sum of the value of the critical nutrients other than protein and energy is determined similarly for each feedstuff and designated as the K value of that ingredient.

CALCULATION OF THE RELATIVE VALUE OF FEED INGREDIENTS

Equations are presented by which one can compare the relative nutritional value of various feed ingredients with corn and soybean meal. These permit rapid calculation of the relative value of feed ingredients at any given price situation. The estimated nutritional worth of various feed ingredients has been calculated based on delivered market prices. These estimates, along with actual market prices are presented in the accompanying table.

With the composition of these ingredients available in the tables, the nutrients in a feed formula are calculated. First, the formulation is indicated on the lefthand side of the page. Columns with headings for each of the nutrients are made. While not absolutely essential, it is customary to reduce the formulation to so many pounds per 1,000 lb of feed. The number of pounds of feedstuff is multiplied by the amount of nutrients per pound, and in each column in its proper place the amount of nutrient contributed by that feedstuff is placed. The amount of the various nutrients is totaled. This will be the total for 1,000 lb of mixed feed. This is reduced to the measurements by which the nutritive requirements for poultry are given and compared with the standard.

Example 1

	% Required	% in Fixed Ingredient	% from Variables
Protein	24	2.20	21.80
Productive energy (Cal per lb)	1032	32	1000.
Total	100	6.55	93.45

Equation (set up)

Line	(Corn)	(Soy)	(Fat)
(1) Protein	8.8 X +	51 Y +	0 Z = 21.80
(2) Energy	1150 X +	640 Y +	2900 Z = 1000.
(3) Total	X +	Y +	Z = 93.45

To remove Z

Multiply line (3) values by 2900

Subtract line (2)

$$\begin{array}{r}2900\,X + 2900\,Y + 2900\,Z = 2710.05\\ \underline{1150\,X + \;\;640\,Y + 1000\,Z = 1000.\;\;\;}\\ 1750\,X + 2260\,Y + \text{——} \quad = 1710.05\end{array}$$

To remove Y from equation

multiply line 1 values by factor 44.313

$$\frac{389.95}{1360.05}X + \frac{2260\,Y}{\text{——}} \text{——} \frac{966.02}{744.03}$$

$$X = \frac{744.03}{1360.05} X\ 100 \qquad = 54.71\%\ \text{(Corn)}$$

$$Y = 21.80 - \frac{(8.8)(.5471)}{51} \qquad = 33.30\%\ \text{(Soy)}$$

Difference Z

$$= 93.45 - (54.71 + 33.30) \qquad = 5.44\%\ \text{(Fat)}$$

Example 2

	% Required	% in Fixed Ingredient	% from Variables
Protein	19	2.2	16.80
Productive energy (Cal per lb)	950	32.	918.
Total	100	6.99	93.01

Equation (set up)

Line	(Corn)	(Soy)	(Fat)
(1) Protein	8.8 X +	51 Y +	0 Z = 16.80
(2) Energy	1150 X +	640 Y +	0 Z = 918.0
(3) Total	X +	Y +	Z = 93.01

To remove X from equation multiply line 1 values by factor 130.681

$$1150\,X + 640\,Y + \quad = \underline{918.}$$

$$— \quad 6024.73\,Y \quad = 1277.44$$

$$Y = 1277.4 \times 100 \quad = 21.20\%\ \text{Soy}$$

$$X = 16.80 - \frac{(51)(.2120)}{8.8} \quad = 68.00\%\ \text{Corn}$$

Difference Z $= 92.01 - (21.20 + 68.0) = 3.81\%$ Fiber

PELLETING

Fifty-six percent of all manufactured feeds were pelleted in 1960. This corresponds to an annual volume of over 22 million tons. Thirty-five percent of the volume of broiler feeds, 14% of the layer feeds, and 60% of the turkey feeds were pelleted.

Pelleting of feed increases body weight and improves feed conversion and thus is of economic advantage with broilers. Pelleting of layer rations consistently increases feed consumption and body weight without a corresponding increase in egg production. A marked improvement from pelleting is noted when barley replaces corn. Responses are obtained from pelleting feeds fed to turkeys during the period from 0 to 8 weeks but not from 8 to 24 weeks.

Moisture is added as steam to feeds before pelleting. Conditioned for pelleting, mash has an average temperature of 183°F. The holding time in the die is several seconds rather than the widely accepted fraction of a second. About 10 to 15% of each crumbilized batch is recycled and repelleted. Fines produced anywhere in the process are expensive for they reduce production rates.

Microingredients are added at levels to suffice for two months in storage.

In view of the severe conditions imposed during pelleting, there are losses from vitamin A sources. The fat-soluble vitamin group is sensitive to oxidation, temperature, moisture, and minerals, but choline chloride and niacin are stable under most normal processing conditions. Calcium pantothenate and thiamine are unstable to moisture, acid pH values, and elevated temperatures. Vitamin B_{12} has poor to good resistance to pelleting. Results are controversial concerning the stability of active enzymes and procaine penicillin. Riboflavin is sensitive to reducing substances, alkaline pH range, and minerals. Thus, prompt feeding of pelleted rations is desired, plus inventory control measures to insure rapid systematic turnover.

Steps in Pelleting Feeds

There are six important steps involved in feed processing to form pellets or crumbles: (1) formulation, (2) conditioning, (3) formation in the die, (4) drying and cooling, (5) granulating or crumbling, and (6) screening and cleaning. Of the various requirements to make good quality pellets, the most important is binding quality since without it, it is difficult to pellet and process into crumbles. Starches are highly desirable since they break down into sugars in the presence of heat and moisture and form a very effective binding agent. The moisture content also affects pelleting, being 15 to 18% for best results. Steam is a practical way of adding moisture and heat in pelleting operations. The pressure of the steam has little effect upon pelleting.

Practically all pellet mills are of the ring die and extrusion type. The ring die is mounted in a vertical position and rotates. The feed is forced and pushed through the holes in the die by rollers. This action is known as extrusion.

Many different sizes and shapes of pellets are manufactured and each requires a different die. The thickness of a die is ten times the diameter of the pellet. A good binding agent makes a harder pellet than any amount of pressure applied in pelleting. After pellets have been formed, the next operation is to dry and cool them. Heat and moisture are removed before pellets can be stored which takes 7 min for pellets of ¼-in. diam. Pelleting produces homogenous feeds, reduces dustiness and dust losses, gelatinizes starches, and brings out the natural oils in grains. Pellets save 9% of the feed of turkeys on range due to reduced wind losses and improved feed efficiency.

A number of types of binders are used to improve pellet durability and pelleting efficiency. Thick dies and high conditioning temperatures increase pellet durability and efficiency. Obvious advantages are that pellets can be handled easily in bulk like grains, dry and dusty sacking in the mill are eliminated, and dust losses around the mill are kept to a minimum.

Cooling pellets is easier than cooling meal. Pellets take half the space in storage as meal and handle better in bins, conveyors, and hopper cars.

Making Crumbles

Crumbles are made from pellets. The amount of fines in crumbling is determined by the quality of the pellet and the way it is bound together. Sharp, corrugated rolls are used. The final product made from regrinding pellets to crumbles is more compact, free-flowing, and uniform than conventional meal, as well as less dusty.

Cost of Grinding

It costs nine times as much to grind oats fine as it does to grind them coarse. The power cost of grinding corn fine is four times as much as for coarse grinding. As the fineness increases, the capacity of the grinder drops. Capacity of a mill is increased to four times as much feed per hour with coarse grinding as with fine grinding. There is nothing to be gained nutritionally from feeding finely ground feed.

The purpose of milling grains is to make the endosperm available to digestive juices. This is accomplished by just barely cracking the ectoderm or by pulverizing. Digestibility is improved somewhat with fine grinding because of more rapid passage through the digestive tract. Conditioning grain with steam at a temperature of 200°F adds 9% water and makes the grains sufficiently soft to become flaked by rolling. Heat treatment causes protein denaturation and the Maillard reaction may under conditions of limiting amino acids availability result in decreased product value. Grain enzymes, alpha and beta amylases, are not inactivated by the process. Starch gelatinization and protein denaturation occur in the outer part of the pellet. Friction and shear cause biochemical changes during compression of feed in the die holes. Heat of extrusion penetrates only slightly into the pellet. Some grain varieties and hybrids are more easily gelatinized than others, as measured by susceptibility to enzyme digestion.

Pellet Binders

There are many binders which contribute to better pellet quality—lignosulfonate, bentonite, soft phosphate, gelatinized starches, and molasses. There is a growing demand by feed manufacturers to be able to add considerable molasses to some formulations as a pellet conditioner. Molasses is delivered to the conditioner in a state of low viscosity so it mixes uniformly into the mash. Molasses at 100°F is pumped, controlled, and metered into the conditioner. Steam is introduced into the molasses line 3 ft from the discharge at the conditioner. The steam traveling at a high velocity relative to the molasses, mixes and heats it adding moisture by condensation. When

it hits the dry mash it penetrates almost completely instead of merely coating the particles.

Important factors for a good crumbling operation include: (1) a quality pellet cool and dry, (2) uniform feeding to the rolls, (3) proper adjustment of the rolls, (4) the maintenance of a sharp corrugation to permit a cutting rather than a crushing action, and (5) 10% of oversize particles for return to the crumble roll. The addition of fat after pelleting rather than before improves the quality and durability of high-fat pellets and usually these are the only pellets with over 4% fat that can be made.

The expansion methods of cooking grains are of increasing interest. The coarse structure and bulk density from expansion is just as important as the cooking. The expander consists of a tube containing breaker screws and worm shaft with interrupted flights. At the discharge end of the tube there is a flat plate containing a number of small openings through which the material is extruded. The number and size of these openings can be varied for different materials. The only pretreatment is grinding. Water and sparge steam are injected into the tube through valves. The material is cooked by the steam and heat from the friction of the rotating shaft. The pressure exerted within the tubes keeps moisture in a liquid state but immediately upon discharge it vaporizes which causes materials to become puffed or expanded. In the process, water is injected to bring the moisture level up from 10 to 20%. Enough steam is injected to raise the moisture content from 15 to 35% and the temperature between 120° and 190° F. The pressure exerted upon the material is 100 psi. At the die, the material is heated mainly by shaft friction from 200° to 420° F and placed under pressure from 200 to 1,500 psi. Retention time in the expander is about 30 sec. The cook, therefore, lasts only a relatively short time. Starch is the ingredient which allows the material to puff and puffing is influenced by the amount of starch present. A typical cereal grain can be expanded 4 diam. Enzymes are deactivated by the expansion.

Advantages and Disadvantages of Pelleting Feeds

Advantages of pellets include the following: (1) feed wastage is minimized (feed spilled from hoppers can be picked up again in floor-type operations but not in cage operations); (2) each pellet is a balanced ration so selection of ingredients is prevented; (3) less total feed required; (4) improves palatability; (5) less feed storage and feeder space is required as a result of increased density; (6) destruction of any growth inhibitor; (7) pellets are readily adaptable to automatic feeders; and (8) some reduction in *Salmonella* contamination.

Disadvantages of pelleting are: (1) added cost of manufacture; (2) possible destruction of some micronutrients; (3) increased water consumption with

associated problems of litter condition; and (4) increased cannibalism or feather picking.

Use of Mashes

For many years, poultrymen were advised not to change mashes suddenly, particularly the physical size of the particles. Recent tests have shown that this is not true. In the State of Washington, laying birds consumed and utilized with equal efficiency mashes varying in texture from coarse to fine. The coarsest ration was prepared from dry rolled wheat, corn and oats ground over 1/4-in. and 3/16-in. hammer mill screens, respectively, and coarse unground wheat mixed feed. The finest ration had all 4 grain products through 1/16-in. screen. The texture of the mash was also changed suddenly and this did not affect the rate of lay. In a study on the effects of changes in ration color, equally good feed consumption and performance of the birds were secured when using red wheat or white wheat. Feeding the mash in pellet form increased feed consumption which resulted in greater body weight but not greater egg production.

Oklahoma tests also showed comparable utilization of coarse and fine ground rations. Grinding of feed to a powdery state confers no additional nutritional value, decreases palatability, and is itself a relatively costly process. Fine grinding of the feed is, therefore, not advisable for poultry. Given the value of mash as 100, the average in the gains in weights of birds fed crumbles was 110%, with a range of 91 to 129%. Crumbles consumed per 1 lb. of gain was 96% of the mash. Although crumbles made superior gains and better feed efficiency, there was wetter litter and more feather picking.

On the scientific level, the reasons for the efficiency of pellets are far from being fully understood. One reason why pellets do well compared to conventional mash is because they are 25% heavier than mash. Because of this greater density, the birds consume less feed to get the same amount of nutrients and there is less waste. With turkeys, there is a small difference in intake between complete feeds and free-choice protein concentrates and milo. There is some seasonal trend since more grain is consumed in cold weather. For turkeys from eight weeks of age to market there is no significant difference between pelleted and mash forms. Making feed more compact increases consumption, especially in the case of bulky materials. It is difficult to handle bulky ingredients by automation. Pellets also require much less space in storage than mashes.

South Dakota State University researchers have found that the particle size of feedstuffs determines its antirachitic value for poults. The smaller the feed particle size, the higher the incidence of rickets. This was demonstrated with soybean meal, casein, and isolated soybean protein. No ex-

planation for the effects of finely ground feed on the incidence of rickets has been demonstrated so far but calcium:phosphorus absorption may be affected.

Paste Feed

Paste feed is a term applied to a blend of a complete feed with sufficient water to insure wetting of all particles with a minimum of free water. Most feed mixes require addition from 1.3 to 1.5 parts by weight to every part of dry mixed feed. Paste moves through pipes as a plug would rather than flows. If movement in the pipe is stopped, all particles remain essentially stationary until movement is started again. No settling occurs. The basic goal of paste feeding is a piping system for movement without the disadvantage of excess water. Advantages are: (1) feeding and distribution equipment are simpler and less expensive; (2) no excess material is pumped, either water or air as compared to the slurry or pneumatic systems; (3) no dust is generated by the feed; (4) less feed is wasted because paste feed is more readily consumed and does not splash or blow away; (5) separation of feed components during transport is not a problem as in slurry, pneumatic or mechanical feeding systems; (6) the pump required to move paste feed functions as a metering pump; and (7) the blending and metering of paste feed provides means of accurate medication or inclusion of feed additives with a negligible loss in potency.

Paste feeding systems have certain limitations. They must be protected from freezing temperatures, and power requirements are higher than for some mechanical systems. Corn is ground through no larger than 3/16-in. screen for proper pumping. Care must be taken to provide fittings and valves in piping with smooth interior walls with a minimum of ledges and offsets. Paste feeding systems have been used more with pigs than chickens.

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STORAGE

Storage affects the nutritive value of grains depending on the moisture content, temperature, degree of maturity at which the grain is harvested, the manner of handling from the time harvested, the type and construction of storage bins, and the length of time of storage Whole grains store better than ground grains. Deterioration of grains is accelerated by high temperatures and retarded by low temperatures.

Changes in Nutrients

Fats form free fatty acids which reduce palatability; in fact, free fatty acid content is a useful index of general deterioration. Thiamine, riboflavin, vitamin E, carbohydrates, and mineral constituents are, in general, unaffected during storage, although the availability of phosphorus is affected adversely. Ground grains become rancid more quickly than whole grains; when ground grains are mixed with good feed they make the entire mixture unsatisfactory. Heat and moisture encourage this deterioration causing tallowy odors and flavors. Rancid oils and fats destroy certain vitamins. Storage produces changes in the physical and chemical properties of proteins. Cryptoxanthin content of corn and carotene content of alfalfa decrease with storage. Half the carotene is lost during storage for a summer. Exposure to light, air, and moisture increases carotene loss. Sacking the meal in airproof and moistureproof sacks reduces loss, as does storage in airtight bins in which the air is replaced by nitrogen. Fish oils, stored under conditions of heat, light, and moisture, rapidly oxidize and destroy vitamin A. Fish liver oils should be purchased in small containers; oil purchased in large drums can be drawn off from the bottom through a faucet without allowing air to pass through the oil.

Corn completely cured and dried before going in storage does not change

as much as if stored directly after harvest. Soybeans with higher moisture content are greater risks than beans with lower moisture content, although the storageability of higher moisture beans can be extended at low temperatures. Grains that mold in storage give poorer feeding results than sound grains. Protein value of freshly-harvested ripe corn decreases rapidly during the first few weeks of storage, but after 12 months no significant decrease occurs.

Propionates in feeds minimize heating of beans, particularly enroute to destination. Feed mixtures heat eventually when the moisture of hygroscopic ingredients in the feed goes above acritical level.

When the germ of the seed is destroyed, natural antioxidants such as vitamin E disappear and the grain is difficult to store. Early freezing before the grain is dried down and matured destroys or damages the germ of the grain. In seed corn, for example, if the temperature falls below the moisture content of the corn, the germ can be damaged. Corn is considered mature at 35 to 38% moisture. A temperature of less than 32° destroys the germination of 35 to 38% moisture corn. Heat from drying of grain can be harmful. The higher the moisture content of the grain, the faster the germ is destroyed by drying.

Grain stored for more than a year loses some of its germination. Mold damage may occur in the field or in storage. Sprouted grain has a dead germ when dried. Mold damage may be present in the germ or in the whole kernel. The germ of a seed is dead before it becomes invaded with mold. Dead germ grain forms pockets in storage so it must be moved or aerated so that sufficient air is available and it is cooled down. Such grain should not be blended with high moisture corn. The moisture and temperature content of such corn must be watched very carefully; moisture rise of ½% in stored corn indicates the beginning of spoilage.

INSECT DAMAGE

Most of the damage done by insects to grain in storage is brought about by four species of insects: granary weevil, the rice or black weevil, the lessor grain borer or Australian wheat weevil, and the Angoumois grain moth. The primary pests are not ordinarily capable of a free existence outside the kernel, but live entirely within the kernel where they feed unseen and unsuspected. These pests cannot be removed by ordinary grain cleaning machines. If the grain kernels are broken, secondary surface feeders take over. The latter can be largely removed by grain cleaning operations.

Prevention of Infestation

To prevent infestation after harvest, store dry grain in weathertight, rodentproof bins, preferably of steel. Clean out all bins before loading with grain and spray walls and floors of wooden bins and around door frames of

metal bins with pesticide. Clean and dispose of litter, waste grain, and feeds that have accumulated around farm buildings. Apply effective powder or spray directly to the grain as it is binned or fumigate promptly after binning. Inspect monthly and fumigate if an infestation is discovered. Exposure to freezing climate kills infestations in ear corn stored on the farm so that loss from insect attack is inconsequential if corn is to be used for food during the ensuing season. Information regarding the prevention of infestation or the treatment of infested grain is contained in publications obtainable from the U.S. Dept. of Agr.

Losses from Infestation

Insects in farm-stored grains cost American farmers millions of dollars every year. Some is destroyed by insects and the remainder made unfit for human consumption. Yet, the loss is preventable. Watch for insect buildup and fumigate if necessary. Fumigants are sold under various trade names, ingredients of which are shown on the label. Follow the manufacturer's recommended dosage and apply from the outside of the bin. About every month take probe samples from the center of the bin and inspect for insects.

Insect Life Cycle

The life cycle of these insects consists of four stages: adult, eggs, larvae, and pupae. Most insects hatch from eggs. A typical insect, the confused flour beetle, has eggs only 1/5 in. long and hatch in about 10 days under summer conditions. The larvae or worms are very small when they first emerge from the eggs; as they eat and grow they shed their skins and change from larvae to pupae which do not move about or feed. During this stage the larvae is transformed into an adult beetle with wings. During the pupae stage which lasts about ten days, adult organs can be seen through the thin skin which is to be molted when the adult emerges. The larvae of most moths and of a few beetles form a cocoon in which the pupal stage is spent. Adult insects mate and lay eggs. Adult beetles live and feed for a year during which time they crawl and fly about. Adult moths feed very little, if any, and live only a few days or weeks.

Heating Effects from Insects

Grain-infesting insects can cause heating in small grains and shelled corn as a result of their feeding and other activities. This is called "dry grain heating" and may bring the temperature of the grain up to 108°F. The warm air from the heating grain rises to the surface of the grain mass carrying moisture with it. At the surface the warm air is cooled and some of the moisture is deposited on the surface of the grain where molds and fungi develop and cause caking and spoilage of the grain. Insect-caused

heating develops in grains of less than 15% moisture content. Heating that occurs in grain with higher than 15% moisture is "wet grain heating" and comes from the activities of yeasts, molds, fungi, and the respiration of the stored grain itself. In this type of heating the temperature of the grain may rise as high as 144°F. Insects cannot survive under these conditions. Both dry grain and wet grain heating may develop simultaneously in different parts of the same bin. All feed mills become infested at one time or another. Realizing the importance of maintaining a clean plant, managers fumigate one or more times a year as a general practice. It is less costly to operate this way than to let the condition become so bad that they are forced to shut down the mill for a thorough cleaning and fumigation. Successful fumigation is assured only with a tight bin and a temperature above 65°F.

RODENT CONTAMINATION

Grain is also destroyed or contaminated by rats and mice, which each year destroy many millions of bushels of grain and feeds. They are also the source of diseases that are deadly to humans, pets, livestock, and poultry. Control consists of: (1) not giving them shelter, (2) not feeding them, (3) killing them, (4) organized community rat control projects, and (5) following a year-round program. Remove places where rats and mice can hide, including piles of rubbish, stacks of old lumber and other materials, and wooden floors close to the ground. Check doors and windows to prevent rodent entry and raise the floors of chicken coops and granaries 18 in. or more above the ground. Store feeds properly and keep trash in ratproof containers. Make granaries, corn cribs, feed rooms, and storage rooms ratproof.

Control of Rodents

Rats and mice that are hungry are easily killed by poisoning and trapping. Poisons should be handled with great care and kept away from children, livestock, and pets. They are only as effective as the bait with which they are mixed which should be fresh and clean. Warfarin, a slow-acting poison is an anticoagulant chemical which increases clotting time of the blood causing death by internal bleeding and must be consumed in small quantities over a period of several days. Adult poultry are very resistant to the chemical. Warfarin is a good follow-up rodenticide to use after infestations have been quickly reduced by other control methods. Many ready-mixed baits contain red squill. When using the poison, use covered feeding stations which permit entry of rats and mice but exclude large animals. Fumigation with cyanide gas or gasoline exhaust fumes is effective in control of rats in outside burrows, but should not be used indoors. Calcium cyanide dust is

usually applied with a special dusting pump. Traps are used where poisons or fumigation would be unsafe. A properly placed rat trap needs no bait. Mice are easily trapped in ordinary snap traps baited with peanut butter and rolled oats.

Community action is the most effective way to fight rats. Community campaigns should include not only farms but dumps, feed mills, and other food storage areas in towns or villages. Rats raise 4 or more litters a year, averaging 6 to 10 in a litter. The presence of 1 pair of rats on the premises in the spring can mean 50 rats by fall. Rat control, therefore, must be a continuous job. Once their numbers are reduced in a community, they can be kept down at little cost by maintenance control. Modern rat poisons not only kill the rat but cause them to leave the building before dying. Precautions in new construction and simple repairs in old buildings aimed at the exclusion of rats should precede any control method. The cost of supporting only 1 rat has been estimated at from 50¢ to $2.00 a year. If rats are eating poultry feed, every 3 rats killed will save enough feed to take care of 2 hens. Cleanliness is the worst enemy of rats. Rats will not remain long in a building where all feed is kept in ratproof containers.

Fumigation

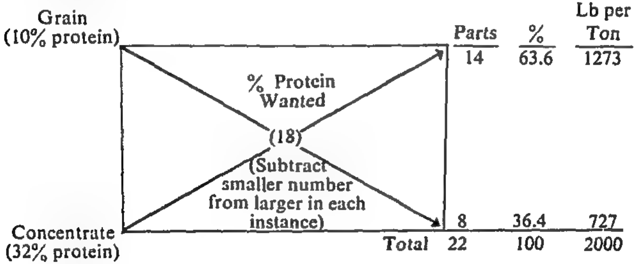
Closed recirculation is 1 of the 3 basic methods of fumigation. Others are the gravity penetration method and the single pass method. Besides outperforming the other methods, closed recirculation also eliminates fumigant losses caused by minor difficulties usually associated with the single pass method. Closed recirculation is the most effective way to fumigate grain in flat storage buildings.

PART 2 Ration Computation

INTRODUCTION

Local feed mills buy prepared protein concentrates to mix with corn. Corn has 9% protein and the concentrate 42%. It is desired to mix this corn and concentrate to get 16% protein. As shown in the accompanying figure put the desired percentage protein in the middle of the square and the percentage available in the feeds to be blended in the left corners. Subtract the smallest number from the largest diagonally. This is then 26 and 7. Add these together to become 33. Thus, combine 7 parts concentrate and 26 parts corn to make 33 parts of 16% protein laying ration. With Pearson's square only two inputs, corn and a concentrate, can be used. When the grain is ½ corn and ½ oats, you put corn as only 8% and oats as 12% and again you can put ½ of your grain coming from corn and ½ coming from oats. Multiply as shown below to come up with a 10% grain mixture.

A method for calculating how much grain should be added to a concentrate to obtain a specified percentage of protein



Example:

A poultryman has a 32% growing mash concentrate to be mixed with grain. He wants an 18% protein complete ration for feeding replacement birds from the 7th through the 10th weeks. Calculate as shown above.

In this example, it was stated that the protein content of the grain was 10%. If a grain mixture is to be used, calculate the percentage protein in the grain mixture as follows:

Suppose a grain mixture contains—½ corn and ½ oats

Corn has	8% protein × ½ =	4
Oats has	12% protein × ½ =	6
		10% protein for grain mixture

GUIDELINES

Some guidelines may be of interest in working out a problem. Corn and soybean meal are used in the Midwest as the chief feedstuff of which a poultry ration is manufactured not because they are better than other sources but because of economics. Another ingredient often found is alfalfa. Color is needed in the yolk. In order to get acceptable yolk color, 2 to 3% of alfalfa is needed. Fishmeal represents 2 to 3% of many laying rations, usually not more than this because of economics; meat and bone scraps usually 1 to 5%. Other ingredients: distillers' dried solubles, poultry by-products meal and feather meal, possibly 1.5 to 2.5%. Whey is used at low levels. Fats and oils are used in almost all rations with the exception of starter and developer rations up to 2.5%. More and more fat is finding its way into laying rations. Salt is added usually between 0.25 and 0.5% to every ration.

There are a few guidelines concerning use of critical ingredients in formulating rations. It is necessary to know whom the formulation is for—whether starting chicks, pullet replacement, broiler, turkey ration, or whatever. Suppose a 16% layer ration is to be formulated. You have 30 to 50 choices of ingredients. In feed manufacturing, vitamin trace mineral premixes are frequently used. These run from 0.25 to 0.5% of the ration. Figure out everything except corn and soy. Arbitrarily assign 3% fishmeal, 2% alfalfa, ½% fat, 6% limestone, and 1½% dicalcium phosphate. Calculate the protein from all ingredients other than corn and soy. In order to account for 100% of this ration, find out how much is obtained from ingredients other than corn and soy.

BALANCING PROTEIN AND ENERGY IN POULTRY RATIONS

Many nutritionists use the "rough estimate" method for balancing protein and energy in poultry feeds, whereby ingredients are increased or decreased by trial and error. However, it is possible to balance exactly protein and energy levels in the feed by the use of simultaneous equations at a considerable saving in time.

The following shows how these equations are used in formulation when dehulled soybean meal and fat provides the desired energy level in the ration. Steps to follow are listed.

(1) List all ingredients in percentages and calculate nutritional worth, with exceptions of yellow corn, soybean meal, and supplementary fat or fiber.

(2) After determining the exact amounts of these fixed ingredients (animal protein, mineral requirements, vitamin and additive products) obtain:

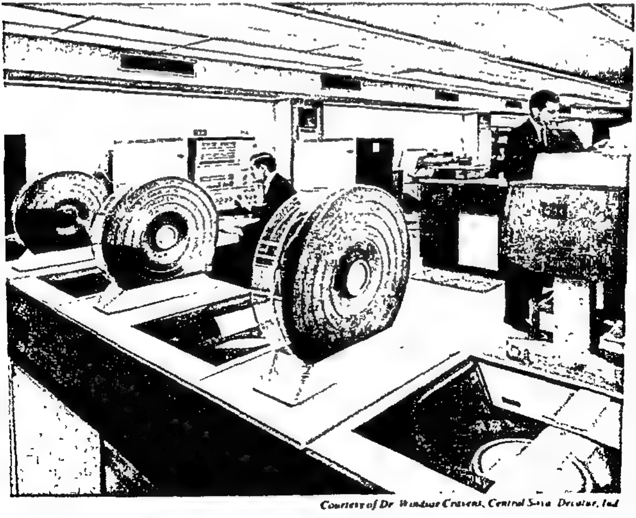
   (a) Percentage protein provided by the fixed ingredients.

(b) Percent of 100% that the fixed ingredients comprise in the tentative formula.

(c) Calories of productive energy provided by fixed ingredients.

COMPUTERS

Computers are used for formulating least-cost poultry feeds which should not be confused with lowest-priced feeds. The former means that this is the lowest cost formula that contains all the nutritional elements needed for maximum performance. The latter may not be the formula that will produce maximum performance which depends not only on the price of feeds but also on efficiency of utilization. Many factors influence daily feed consumption of laying hens. Among these are size and breed of hen, environmental temperatures, age of hen at start of egg production, type of housing, feeding space for hens, depth of feed in automatic feeders, whether or not the hens are properly debeaked, degree of crowding of hens in cages, availability of ample cool drinking water, disease level in the flock, and energy content of the diet. Heavy breeds consume considerably



Courtesy of Dr. Windsor Cravens, Central Soya, Decatur, Ind.

FIG. 26.1. THE COMPUTER IS BEING USED BY THE FEED INDUSTRY TO SOLVE COMPLEX PROBLEMS IN FEED MANUFACTURE

AMOUNT	INGREDIENT NAME	COST
450.00	SOYBEAN ML SOLV-44	3.75
5.00	LIMESTONE	.78
50.00	FISH MEAL, MENHADEN	7.00
20.00	FAT, ANIMAL, STAB	4.75
100.00	ALFALFA MEAL, DHY 17	2.02
50.00	MEAT & BONE SCRP. 50	4.42
5.00	SALT, TM-POULTRY	1.35
20.00	CDP 18–32	3.36
250.00	OATS, PULV.	4.25
900.00	CORN, GR YEL.	2.28
85.00	WHEAT MIDDS, STD.	2.60
32.00	FIXED INGREDIENTS	22.00
50.00	WHEY-MNC	5.00
	2017.0 @ $	68.65 PER TON

A	A_1	B	C	D	E	F	G
AMOUNT	INGREDIENT NAME	SCALE READING	COST	LOW RANGE	HIGH RANGE	INGREDIENT MIN.	MAX
1052.5	CORN, GR YEL.	1052.5	2.28	1.39	2.80		
498.1	SOYBEAN ML SOLV-50	1550.6	4.05	2.59	4.07		
143.6	ALFALFA MEAL, DHY 17	1694.2	2.02		2.01		
126.8	WHEAT MIDDS, STD.	1821.0	2.60	2.24	3.15		
50.0	WHEY-MNC	1871 0	5.00			50.0	50
37.5	CDP 18–32	1908.5	3.36	1.23	6.25		
32.0	FIXED INGREDIENTS	1940.5	22.00			32.0	32
25.0	FISH MEAL, MENHADEN	1965.5	7.00	6.29		25.0	
20 0	FAT, ANIMAL, STAB	1985.5	4.75	.25		20.0	
9.5	LIMESTONE	1995 0	.78		3.33		
5.0	SALT, TM-POULTRY	2000.0	1.35			5.0	5
	Rejected in solution		$64.01 PER TON				
	OATS, PULV.		4.25	2.12			
	SOYBEAN ML SOLV-44		3.75	3.74			
	MEAT & BONE SCRP. 50		4.42	3.58			

Courtesy of Computrol Systems Inc

FIG. 26.2. LINEAR PROGRAMMING TO OBTAIN LEAST-COST COMBINATIONS OF FEEDSTUFFS TO IMPROVE ECONOMICS OF FEED MANUFACTURE AND ANIMAL PRODUCTION

	H	M	I	J	K	L
UNIT	RESTRICTION	ORIG.	MINIMUM	ACTUAL	MAXIMUM	NUTRIENT COST
Cal/lb	MET ENERGY	1243.63	1243.00	1260.00	1260.00	.0009
Cal/lb	PROD EN.	912.49		913.23		
%	CRUDE PROT	20.10	19.00	20.51	22.00	
%	ARGININE	1.31		1.35		
%	LYSINE	1.08	1.08	1.11		
%	METHIONINE	.36		.36		
%	METH & CYST	.69	.69	.69		1.2562
%	TRYPTOPHANE	.26		.28		
%	GLYCINE	1.05		.96		
%	HISTIDINE	.45		.47		
%	LEUCINE	1.66		1.74		
%	ISOLEUCINE	.94		.99		
%	PHENYLALANINE	.94		.99		
%	PHENYL & TYROS	1.63		1.69		
%	THREONINE	.78		.82		
%	VALINE	1.01		1.02		
%	CRUDE FAT	4.39		3.90		
%	CRUDE FIBER	5.61		4.40	4.40	.0617
%	ASH	5.92		6.17		
%	CALCIUM	1.00	1.00	1.05	1.05	.0672
%	PHOSPHORUS-AVAIL	.55	.55	.55	.57	.1191
%	PHOSPHORUS-TOTAL	.82		.83		
%	SALT	.67		.39		
%	SODIUM	.33		.39		
Mg/lb	MANGANESE	30.22		30.27		
Mg/lb	ZZNC	34.42		34.09		
Mg/lb	IRON	86.42		116.50		
Mg/lb	COPPER	5.54		4.82		
Mg/lb	IODINE	.50		.49		
Mg/lb	XANTHOPHYLL	9.67	9.67	12.44		
Mg/lb	CAROTENE	3.38		4.78		
KIU/lb	VITAMIN A	1.69		2.39		
ICU/lb	VITAMIN D-3					
IU/lb	VITAMIN E	6.59		8.75		
Mg/lb	VITAMIN K					
Mg/lb	THIAMIN	2.21		1.76		
Mg/lb	RIBOFLAVIN	1.69		1.87		
Mg/lb	NIACIN	12.80		12.79		
Mg/lb	PANTOTHENIC ACID	5.46		5.27		
Mg/lb	CHOLINE	543.74		500.86		
Mg/lb	PYRIDOXINE	2.75		3.09		
Mg/lb	FOLACIN	.35		.38		
Mg/lb	BIOTIN	.08		.07		
Mcg/lb	VITAMIN B-12	3.94		1.63		

FIG. 26.2. (CONTINUED)

more feed than light breeds because heavier chickens require more energy for maintenance. A modern strain of small White Leghorns, however, receiving feed containing the same energy level under the same environmental conditions would consume considerably less feed per day and, therefore, would require a higher protein level. Computer formulation of least-cost rations to contain the exact amounts of nutrients needed by hens makes it absolutely essential that the poultrymen keep accurate records of daily feed consumption. This allows the feed manufacturer to adjust protein, mineral and vitamin level to meet exactly the daily needs of the hens for maximum egg production and maximum efficiency of feed utilization.

It is beyond the scope of this discussion to outline detailed procedures for linear programming. In general, data is put on punch cards and then on magnetic tape. The latter is run through a computer which has been programmed to solve the problem within the restrictions placed upon it by the programmer. The programmer sets up a schedule which relates the various bits of information to the problem at hand. Douglas Division of the Borden Chemical Company, through Mr. Perry Twining of Computrol Systems, Inc., came up with the least-cost ration shown from data submitted by the author. Computrol is a small computer used widely by the feed industry

TABLE 26 3

ALL-MASH LAYING RATION

Ingredient	Amt per 100 Lbs	Protein %	Calcium %
Yellow corn	69.43	5.902	0 014
Soybean oil meal, 50%	15.92	7.960	0.040
Fishmeal, 60%	3.00	1.800	0.153
Alfalfa meal, 17%	2.00	0.340	0.030
Animal fat	1.50	...	...
Ground limestone	6.00	...	2.280
Dicalcium phosphate	1.50	...	0.390
Salt	0.35	...	...
Methionine	0.05	...	...
Vitamin-trace mineral premix	0.25	...	...
Total	100.00	16.002	2.907

Method of Calculation

(1) Calculated analysis of current diet

This is a "breakdown" of the current diet in which the computer is given the amount, in pounds, and cost per 100 lb of each ingredient in the present formula. The computer, from the above information, calculated the following:

(1) Total number of pounds

(2) Cost of diet in dollars per ton

(3) Analysis of each nutrient component in predetermined units

(2) Chick Starter least-cost formulation

(A) Activity of ingredient or amount used in least-cost solution.

(A_1) Complete list of all ingredients offered.

(B) Cumulative scale reading—simple addition of col. A. In re A and B, an additional option on console can request round-off to nearest 1 or 5 lb. of selected ingredients as desired.

(C) Price of each ingredient, in $ percent, offered in the problem.

(D) Low Range—Assuming that the price of all other ingredients remain constant, this figure represents the price to which this ingredient would have to drop before more of it would be called for in the solution. For the ingredients rejected in the solution this represents the "nutritional worth" of this ingredient in the problem. This is commonly called the "Opportunity Price."

(E) High Range—Assuming that the price of all other ingredients remain constant, this figure represents the price to which this ingredient would have to rise before less of it would be called for in the solution.

(F) and (G) Ingredient Min and Max—This is input information and represents restraints placed on the problem by the formulator. Such restraints can be used to protect palatability and/or pelletability and gives the formulator an opportunity to pass on to the computer the benefit of his knowledge and experience. Furthermore, the computer can be forced to formulate within certain *supply limitations.*

(H) Restriction Name—Nutrient components upon which the formulator may want to place restrictions either Minimum (I) or Maximum (K). The column J is the actual amount of this nutrient component in the solution.

(L) Nutrient cost—This represents the cost of the last unit of this nutrient which was required to be included in order to meet a minimum restriction; i.e., methionine + cystine, or the cost of excluding a unit of a nutrient in order not to exceed a maximum, i.e., calcium.

These values give an indication of the points of relative cost in meeting certain restrictions when formulating.

In summary the problem submitted for solution is represented by the following:

(A_1) - Ingredients available
(C) - Cost per 100 lb of each available ingredient
(F) - Minimum restriction in pounds per batch placed on ingredients
(G) - Maximum restriction, in pounds per batch placed on ingredients
(H) - Names of nutrient components in matrix

(I) - Minimum restriction placed on nutrient component
(K) - Maximum restriction placed on nutrient component
All of the above represent the input data.
The solution to the problem is included in columns A, B, D, E, J, and L as described above.

Linear Programming

From what has been stated heretofore, it is evident that there is no one best formulation for a poultry feed. Values are based on the nutrients that natural feeds contain. On the basis that there is complete interchange of nutrients among sources, the computer is used to determine least-cost formulas. Linear programming (LP) is technically a mathematical procedure for obtaining a value weighting solution to a set of simultaneous equations. Many solutions to each series of equations are possible but when the factor of cost is applied, there is one least-cost combination. The computer takes information provided by the nutritionist and, being capable of making thousands of calculations in a very short time, determines solutions. Computer input reflects the knowledge and ability of nutritionists. The computer is incapable of correcting human errors so LP results will be no better than the values entered into the machine.

Application to Feed Manufacturing

Application to feed manufacturing is as follows: In choosing feed ingredients to combine in the mix, there are basically two aspects with which to be concerned. (1) The mix must meet quality standards, and (2) the cost must be as low as possible. This can be looked at in mathematical terms. A simple mix problem of 6 quality specifications and 10 ingredients could have millions of feasible solutions. Linear programming has changed the dimension of the problem so drastically that the mathematical model of the mix problem may be meaningful to you. Effort is stressed upon the solutions that are of economical interest for a given set of ingredient prices. This is what is called value weighting. Essentially, the procedure is that of beginning with a solution to the mix problem and considering only a relatively few alternate mixes at one time. If any one of these alternatives is better than the first, the computer selects the one that is best for that set and proceeds to compare it with another set of alternate solutions. This is repeated until no alternate solution lower than the present solution can be found. It is possible by linear programming to determine: (1) a least cost combination of feedstuffs to meet specific nutrient requirements; (2) acceptance or rejection of ingredients based on their cost and nutritive value; (3) effect of variations in nutrient content of feedstuffs on their economic value; (4) final cost of a diet and the cost contributed by each in-

gredient; (5) relationship between requirements for any specific nutrient and the cost of the feed formulation; (6) optimum nutrient density of a diet for maximum economic return to the feed formulator; and (7) cost of replacing any ingredient not in the solution and assistance in ordering feed ingredients.

Necessary Information for Computer

The following information must be supplied to the computer: (1) nutrient requirements or restrictions; (2) available nutrient content of the feedstuffs; and (3) relative costs of the feedstuffs. Except for trial and error method, a hand desk calculator solution of values for ingredients to be used in solving a set of requirement equations is impractical. Eventually, values could be worked out which would satisfy the equations. However, the chance of finding a least-cost solution by hand solution within several working days is remote. A mathematical technique developed for solving a system of formulas has called for the development of more extensive and more exact specifications for feeds.

Computer Limitations

Electronic computers are amazingly efficient and disgustingly lacking in initiative. The computer only does what it is told to do. It is no miracle gadget. Men are available who are knowledgeable in programming so it is necessary to pose problems. Given the right information, they calculate the least-cost formula in the time used for a coffee break, but they do not seem to care whether the formulas are palatable or even completely usable by the chicken. Consequently, the man who formulates the feed and the computer have to work together. The nutritionist must specify what is necessary and arrange in a set of specifications information that will provide the computer the exact limits on which it is free to operate. It is necessary to specify maximum levels of some feed ingredients that are unpalatable, high in fiber, not readily available in large quantity, or subject to other disadvantages. They may be related to toxicity of the material as in the case of cottonseed meal or alfalfa meal. It is necessary to specify minimum levels of some ingredients that provide unidentified nutrients, enhance palatability, or have other desirable characteristics. These are established on the basis of the nutritionist's experience in prior use. It would be nice, of course, if the computer would specify, first of all, that a formula will sell. So far, this is outside its province.

Nutrient Composition Requirement

Knowledge of the nutrient composition of feedstuffs is necessary—average values from tables can be used if the supplies to be used are av-

erage. In the case of specific batches of feedstuffs, it is more accurate to have values for the given lot of material. The other information used in linear programming is the price at the point where the feed is to be mixed and includes transportation costs to that area. Certain ingredients which are constant in use, for example, salt and antibiotics, need not be programmed. From the standpoint of amino acids, methionine and lysine are the two most apt to be deficient. Tryptophan and glycine may be deficient under certain conditions. The remainder of the essential amino acids are ordinarily adequate when most combinations of feeds are used. Since excesses of some amino acids are detrimental, a maximum must be set in these instances.

"LEAST COST FEEDS"

W. V. Waugh of the US Dept. of Agr. was among the first to see the potential of the mathematical procedure of linear programming developed by George B. Danzig in 1947. By 1957, several firms were experimenting with this technique. Among the leaders were G. L. F., McMillen Feed Mills, and Nutrena Mills. In 1958, Dr. Hutton published a series of articles on "The Use of Linear Programming in Formulating 'Least cost' Feeds." This development expanded rapidly among the major feed manufacturers who had sufficient volume to justify the added expense, and in many cases, had electronic accounting systems, computers, and trained personnel available within their own company.

Formula costs sometimes can be reduced by $1.00–$3.00 per ton when calculated on the computers rather than by hand, depending on the number of ingredients used and the fluctuation in their prices. Savings realized through linear programming have usually been passed on to the customer through lower prices.

Ultimately there will be formula changes due to price fluctuations. Formulas may be run as often as desired due to changes of ingredient costs. Feed formulas can be changed and in the hands of the mixer within 30 min. As stated, a problem with computer rations is that there is no easy way to assess palatability. If it is impossible to obtain full consumption of formulated rations, the feeds will not work. Maximum feed consumption is necessary to be valuable as a feed. If feed consumption is limited due to poor palatability, the results will be no better than if nutritional deficiency limits growth. Nutritionists must minimize or be able to assess the sources and magnitude of any variables.

Of what value are computers to feed manufacturing? In one instance, feed costs were cut from 2 to 4%. In order to make a smooth operation for the computer, certain problems must be mastered. With respect to personnel training, employees must be instructed in the data needed and

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how they are presented. All data must be double-checked at every step by personnel before placement into the computer. Solutions of feed formulation problems must be prepared in such a way that when they reach management levels the answers are simplified and concise requiring minimum paper work. Unless an emergency arises, feed formulas are changed weekly.

Computers have already made big contributions to the poultry and feed industry, not only in the formulation of feeds but also in the field of genetics. This is only a beginning. The cost for computer services has dropped drastically in relation to the work that they can do. Modern computers can calculate faster, store more information in their memories, and print results at a higher rate of speed than in the past.

OTHER COMPUTER APPLICATIONS

In addition to the feed formulas, computers are used for breeder egg operations and broiler operations. Flock history, as well as management studies, disease, housing, and equipment are sorted and stored automatically on a random access disc by the computer for future use. The computer can provide hatching egg producers with flock statistics weekly. Future uses for computers are unlimited. Management will be able to have at its desk much information which would be too cumbersome to produce by traditional methods. Information on egg supply, production, forecasts, cumulative averages of disease loss, comparative performance of breeds, when layers can be expanded sooner than otherwise in relation to finished broiler output, anticipated market price, the best time to hedge corn and at what price; all this provides invaluable aid in helping management make major decisions on future capital investments. The computer can help in providing sophisticated forecasting techniques on prices, sales mix, and cash flow needs.

Computers are not cheap. Some cost \$2.5 million and charges are \$330 per hr for use, but they save money. A computer offers all levels of management unusual speed in collecting, assimilating and reporting data in order to facilitate decision making. It can be used to assist in matters of budget, finance, personnel, inventory, purchasing, analysis, and long-range projections. Computers operate by prodigious numbers of high speed additions and subtractions, as well as storage and quick retrieval of immense amounts of data. But these functions do not constitute thinking (the use of judgment and imagination). That is where nutritionists fit into the picture. As the prices of ingredients change, the new costs are fed into the computer and it automatically alters the formula to maintain the nutritional value at the lowest possible price.

In one instance, on the older computer equipment, computer calculations

were made on 252 formulas containing from 8 to 10 requirements and using 19 to 32 ingredients. Machine time for this job was 26 hr, an average of just over 6 min per formula. It seems that linear programming techniques of formulating feed mixes should be at least given consideration by a majority of the feed manufacturers, since in most cases it would permit them to sell a product of equal or superior quality at a lower price.

Linear programming is quite new among the tools of analysis so it is not surprising that many are unaware of its value. The first successful use in feed mixing was published in 1951, so it does not have much of a history. Some important companies in this field are IBM, Control Data Corporation, Univac, and Computrol.

Commercial Use of Computers

Actually, the computer is just a tool that is used to speed up calculations. The Central Soya Co. uses computers extensively. It is engaged in feed manufacturing and soybean processing; it also has a chemical division concerned with the production of isolated proteins and protein concentrates, a grain division and purchasing division. The research department is involved in areas including nutrition research which is conventional, work on drugs and diseases by veterinarians, and effects of environment on animal performance.

Central Soya uses a nutritional standard for every feed including: (1) a complete breakdown of all the nutritional factors or levels; and (2) the composition of the ingredients. This is probably one of the weakest points in formulation. The feed industry uses by-products and these are not uniform in quality and composition. So, it is necessary to be conservative in the values that are applied. Costs of ingredients are obtained from the purchasing departments.

This is how Central Soya's nutritional standard might look. Protein, fat, fiber, minerals, etc., amino acids, and xanthophyll to control pigmentation in the carcass of a broiler or to control the pigmentation of an egg. How many things are not calculated? Vitamins E and K are practically ignored. Vitamin K is in alfalfa. Forced ingredients (those which are to be added irrespective of cost) are used as follows: 3 mg per lb of B_{12}, irrespective of quantity present in the natural ingredients. The values on some of these vitamins and availability, as well as composition leaves much to be desired so they are ignored and put in at a forced level.

What would it mean to calculate vitamin D in most ingredients? It would only make the problem more complex and one would not really gain any useful data. So a certain level of vitamin D is forced. Vitamin A is not considered to any great degree because a stabilized product is used at a certain level. Consideration is given to such things as the effect of an

ingredient on palatability. If too much alfalfa is put in a ration, birds will not eat it as well. At times it is necessary to restrict minimums because of feed registration. In other instances, one must eliminate certain ingredients on the basis of cost but a minimum amount is needed to satisfy feed tag purposes.

If too much fishmeal is added to a turkey ration, there may be flavor problems in the carcass. This is controlled by ingredient restriction. Certain restrictions are made because of production problems. A pellet cannot be made if you use too much of certain ingredients. So, restrictions are made that takes care of that. Cost data come from the purchasing department and the analytical composition of ingredients is submitted to people in the computer area from the research department. Programmers put all these together.

FEED FORMULA ECONOMICS

An ingredient replacement cost sheet is produced for every plant every week. It gives the ingredient code, and costs of that particular ingredient. Actually, what is done is that the people in the computer area will run a whole series of formulas every week primarily in the high usage ones. If there is much change, the formula will be changed. Formulas are changed for a very few cents per ton.

Shadow prices are obtained which help purchasing determine at what cost the formulas will change, and at what cost new ingredients will come in. The formulas derived at are available as code numbers of particular feeds—103 may be a chick starting feed, and include 57% corn, 2% alfalfa, 1% cottonseed meal, etc. Some ingredients are put in because certain ingredients are not carried at a particular plant. Therefore, the price may be put in at $10,000 and this prevents it from coming into the solution of the problem. Milo is used in a Southwestern plant and thus it would be coming in there at the regular price. If milo could be purchased in Decatur, Indiana, for less than $47.92, it would be a good buy. Forced ingredients are not worried about because they are fixed. What do these nutritional restrictions cost? In this particular 21% protein feed, if it could be lowered to 20%, there would be a savings of $1.01 per ton. If it were increased from 20 to 21%, it would cost $1.02. One percent of fat would cost 84c per ton. The reasoning is that it is not affecting price very much because the ingredients are essentially meeting standards. Energy costs 1½c per M.E. calorie. If it were possible to lower the methionine standard 0.1%, there would be a savings of 23c. Here is where the nutritionist must say to himself, this value must exist. If methionine could be lowered 1%, the ingredient cost would be cut 23c. If phosphorus could be lowered to 0.6% the cost would be cut 26c per pound. If phosphorus could be lowered

as well as energy and change some of these things a certain amount, we would experimentally challenge the starter ration. A new solution is made to the problem and then the diet is fed to see what happens. Well, the feeding test indicated that the original standards were much better than was needed. For example, niacin was not costing anything because it was above standard to start with.

If it were possible to lower riboflavin 1 mg per lb, there would be a savings of 6c per ton. Two grams of riboflavin per ton would save 6c. These are values that are very useful and are studied and evaluated. Analytical data for ingredients are not always the same. Margins of safety are needed. An 8% reduction of fiber would save 8c a ton of feed.

Energy within a very narrow range, costs 1½c per Cal. If corn stays at the current price, a new formula would not be necessary. If hominy falls in price, it might be used in this formula. Purchasing can look at this and knowing the trends in the market decide on inventories, what they should be buying, etc. Alfalfa is $48 a ton. Why does a chick need alfalfa? Anyway, it is being forced in at this time. Cottonseed meal is $82.40 and there is a 5% maximum in the chick starter and obviously anything below this cost is going to be sound. It is possible to go up to $85.59 and still use 5%. Meat scraps can vary somewhat without changing the solution to the problem to any degree. These things are the most interesting part of the use of a computer. All feed formulas for experimental work are derived on computers.

Broiler performance is affected by energy and protein levels in the diet. Interrelationships of protein and energy, amino acid level and availability, and other nutritional facts must be taken into consideration. Rations are designed to place an economic value on protein and energy and their interrelationships. It is desired to hold protein quality and other nutritional factors constant as a function of energy. As a result of deciding this experiment using the least-cost approach, it is possible to have been able to draw some rather valid conclusions of where one should operate and get the least cost per pound of broiler meat. This gives the general ideas of how they approach some of their problems. Where economics is a rather major consideration, this is important. The main thing is to gather the maximum number of facts and correlate them.

If the right ingredients are used, the computer will indicate feeds with nutritional variations less than those obtained with hand calculating. Formulas used to change at least a couple times a year. When new alfalfa came in in the fall, the feed got greener in color. With the computer, there was too much variation in color which caused people to think the feed was changed.

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Management of Poultry Operations

A MANAGER

The poultryman is a manager and a manager's job is to secure maximum net income from the resources at his disposal and to combine the "correct amounts" of land, buildings, labor, equipment, and technology. Technology means application of the most recent scientific information on nutrition, breeding, ventilation, and equipment layout.

The manager is the farm's economist. Four sets of knowledge are necessary: (1) the appropriate economic principle to apply; (2) the correct analytical procedure to use in applying it; (3) the latest scientific technology (input-output data); and (4) correct predictions on costs paid and prices received.

It is not an easy or simple job. However, this is the only alternative to "guessing." The managerial function is a skill that is developed with practice. Economic principles can be learned; analytical procedures can be used until they come easily; and pertinent input-output data identified, filed, and kept up-to-date to provide the latest information.

KEEN OBSERVATION NECESSARY

Poultry farming is, however, a worthwhile, satisfying occupation requiring an alert, keen mind and a willingness to work. One must like poultry in order to succeed, for birds are very susceptible to the persons caring for them. The poultryman must observe his birds frequently and otherwise study his business. He must have "chicken sense" or good judgment in caring for and managing his flock. He should acquire knowledge and skill in conducting the business through training and experience. Training is offered in agricultural schools; he can obtain it also by an apprenticeship with a successful poultryman. The poultryman must also know how to deal with people, be courteous, prompt, tactful, honest, and ambitious.

In a small operation the poultryman can do most of the work himself or with his family. As the operation becomes larger he will require more help. A poultryman needs both cash and credit, depending on the size of the enterprise, the efficiency of the plant, and the financial standing of the operator. If a place is rented, less cash is needed. Credit for a poultry enterprise is often available through feed dealers, friends, and banks specializing in agricultural accounts. A method of starting a poultry business is to begin with a small plant and enlarge as earnings increase. There are risks in-

volved. Because of the short life of the fowl there is rapid depreciation of stock which requires frequent renewal. Each year there are the hazards of brooding, rearing, and sometimes incubation. Both young and old stock are susceptible to diseases and parasites. The use of incubators and brooders increase fire hazards.

PRODUCTION AND MARKETING PROBLEMS

A poultryman must understand both production and marketing problems. But there are special advantages of the poultry business and the poultryman has many things going for him. The egg is most universally used of any animal product, except milk. It is essentially "liquid meat" being one of the most easily digested and assimilated forms of animal food. It is relatively easy to get into the poultry business financially and otherwise. There are the quick growth of the fowl, its early and heavy laying ability, and natural vitality to resist disease in its favor. A foraging farm flock can get much of their living from food which otherwise would be wasted.

Relatively small amounts of capital and land are required and there is a quick turnover of capital. It is a healthy vocation and does not require heavy manual labor as do most other kinds of farming. Many women and children on farms assist in the enterprise. Poultry are efficient transformers of raw materials and develop into high priced finished products. About 100 lb of feed and 50 gal. of water are converted into approximately 25 lb of eggs yearly in addition to maintaining the hen. Producers who have established a reputation for high quality eggs frequently receive several cents per dozen higher than the market quotations.

A question often asked by poultrymen, "Is it possible to keep layers a second year?" Some think it is good business to carry the better pullets through the second year but most studies show it is not a good practice. More money is made with an all-pullet flock. Old hens lay larger eggs but the interior and shell quality are poorer.

A popular starting time for egg-type chicks is in the spring. More are started in April than any other month of the year. In earlier times, poultrymen wanted to start their chicks in the spring and then get them out on green grass as soon as possible. With modern rations the green grass is no longer necessary and it is possible to raise them entirely in confinement.

Do layers lay less if the cockerels are in the pens? Experience shows that layers produce as well with cockerels as without. Of course, cockerels eat feed and produce no eggs. The male consumes the same amount of feed as the hen when she is laying at the rate of 50% because the male is larger.

To make your feed do more: (1) buy chicks bred to lay; (2) provide plenty of clean water; (3) provide light to eat and drink by; (4) provide plenty of clean air to breathe; (5) provide temperature between 40° and

70° F; (6) supply all feed nutrients in right amount; and (7) provide enough feeders and waterers spaced properly. A flock of 500 birds divides into about 10 smaller groups of "peck orders." Each group must have its own waterers, feeders, etc; otherwise there is fighting, poor production, and trouble.

THE FEED SERVICEMAN

The business of the serviceman is to assure steady growth of birds and good feed conversion from the start to market. The last week before market is most critical; then, birds eat the most feed and build the most meat. At this point there is a big investment and if anything happens to stress the birds, they slow down and lengthen their growing period; costs rise and profits drop or may be wiped out. That is why it is extra important to keep balanced nutrition and good health to the very end.

The serviceman is the key to profits. Every day he plans his work. Baby chicks come in here, a new building goes up there, or a disease problem exists somewhere. The serviceman has to be on his toes and equipped for any emergency. Working closely with the grower, he aims to better his last record with a new flock. The production chart on one of his flocks looks good with daily feed consumption going up nicely and mortality low.

It is a bother to keep daily feed records but it pays off. A drop in feed intake is the first sign of an undetected disease and can cause a higher rate of condemnation. At one farm, the serviceman noted the feed drop on the same day he saw the birds slipping and heard the sniffle and a few sneezes in the flock. That is the one unmistakable sound of trouble. He recognized a respiratory infection and took sample birds to the diagnostic laboratory. Medication was needed. Some growers prefer water medication; others medicate the feeds, this is mostly prophylactic because sick birds do not eat well. Medication in the water works faster. The serviceman gives the right medication in the right amount, at the right time, and in the right way. Five weeks later, there was not a sign of the setback. Fine looking birds show that waxy, yellow shank, good feathering, and bright eyes. The combination of good birds, good feed, good management, and good cooperation cannot be beaten.

The serviceman's company breeds only the very best stock that are sure to grow. The feed mill formulates high quality feeds, with the proper balance of nutrients from the best materials and best suppliers; feeds designed to speed sturdy, healthier growth with all safeguards included and all the minerals and vitamins proved esssential by long years of scientific research.

Today's feed mill has complete control with big volume mixing; processing is handled by automation. With techniques proved effective, microingredients and drugs are blended and premixed before they are

added to the feed. Carriers in the premix hold important trace elements. The exact amount of this premix is added after 25% of the batch, for which it is formulated, is in the big blender. So, the precise and controlled job of mixing and blending puts profit into every bag of feed. Sampling for analysis provides another quality control. When this feed goes into feeders, the serviceman can be sure it meets every specification of the formula. Feeds are analyzed for uniformity by mill control chemists or outside laboratories. When flocks reach the market the final proof of correct blending and mixing is evident.

The starting of a new flock is critical. A fresh, clean, well-ventilated house is needed. The serviceman makes a careful check. Temperature must be exactly correct for incoming chicks. A good start helps insure a good investment.

Disease Carriers

Wild birds carry disease. They enter the buildings through the front doors, holes, faulty window screens, etc. These places must be watched carefully. Trouble can enter through the front door on strange feet. Better wear protective boots. Older birds can carry typhoid and other diseases. The warning signs of diseases are easy to hear and see but autopsy gives more clear-cut evidence. Servicemen are not trained pathologists. They depend on laboratories for full diagnosis. The serviceman's job is management. Disease detection and consultation on housing are very much his business. He makes available construction plans with vapor barriers and other insulating materials that do great things in temperature control and pay off in better birds.

Modern poultry growers are looking ahead. The three-story house is a far cry from the old one-story buildings. Seventy thousand birds may soon be housed in one enormous building. There is not much excitement in good housekeeping but attention and common sense are the foundations of all chicken raising.

Complete Checks Made by Servicemen

Good servicemen do not miss a thing. What about the level of waterers and feeders? Get the type to avoid spilling and raise as the birds grow. How about temperature? A little on the high side? An extra fan may be needed. Nothing wrong possibly, but it is always wise to make sure. Possibly there is no sign of disease. Perhaps the most satisfaction is the spirit and cooperation between men in all facets of the poultry industry. Servicemen, technical experts, and scores of scientists are helping growers. Members of a great team, they join forces to combine their skills and abilities. When disease strikes, everyone organizes his force with action. Usually

servicemen work with local laboratories who can identify the problem and diseases. The trained eye of the technical expert can be very essential. Feed consumption going down? Sample the feed. This helps in a complete diagnosis. Look at the birds; are many still lively but the color of the feet and legs a little off? Or is there some heavy breathing and maybe a few birds are down? An inside look will tell more. The big job is quick action. A preliminary diagnosis, immediate medication to cut down mortality and halt or stop disease may save them for market. Perhaps they have a low-grade infection which is not too serious. Immediately a program of treatment is initiated. Check further in the laboratory to confirm findings.

The servicemen see that those responsible live up to their contractual obligations. Among the benefits accrued are monetary settlements for failure to fulfill contracts, keeping suppliers on their toes since they know they are being checked, building a history of supplier performance and consistency, and allowing the feed manufacturer to reject lots of ingredients that are not usable in his mill.

FEED WASTAGE

Wastage of 1 lb of feed per day per 100 chickens would be hardly noticeable in a cage or floor-type operation. Yet, it adds up to the difference between profit and loss in some cases. How can this feed wastage be reduced? Consider the following.

Improperly adjusted feeders result in more wastage than anything else with floor birds. Proper height is where the lip of the feed trough is 1 in. above the level of the back of the average-sized chickens. Improper debeaking is a factor; scoop-billed birds must have deep feed or they waste a lot of feed just attempting to eat.

Rats and mice not only eat a lot of feed but they also ruin a lot more and spread disease. Control rodents the year around. Delivery men in a hurry waste feed around the feed bins. Bring this to their attention. Filling hoppers too full will result in birds spilling out feed. Feed more often if necessary.

DAY-OLD CHICKS OR STARTED PULLETS

Should day-old chicks be purchased and raised into pullets or should "started pullets" be bought? There is no one answer to this; it varies from farm to farm and area to area. Some advantages and disadvantages of pullets are as follows.

Advantages

(1) Better use of time may be obtained by becoming a specialist in egg production; (2) better use of buildings and equipment may be made (other

than for brooding and raising chicks); (3) no money tied up for long periods and money will be saved which would otherwise be invested in brooding facilities; (4) the risks of starting and growing chicks are cut; (5) the disease hazard if on an all-in, all-out program is reduced; (6) better pullets may be purchased at a cost less than the cost of raising them; and (7) the culls in the laying house may be reduced because of the purchase of Grade A pullets.

Disadvantages

(1) Disease hazard; (2) may increase costs (the grower has to make a profit too); (3) it is not always possible to get started pullets of the strain desired; and (4) the feeding program or management that has been employed previously cannot be controlled.

In an area of mass production, efficiency of management is the price of survival. The change from open range to confinement-rearing under crowded conditions has emphasized the importance of correct management practices. The trend is toward larger, more efficient production units, making use of labor-saving equipment. This requires larger capital investment. Eighty percent of the poultry meat and 50% of the eggs marketed in the United States are from large commercial flocks fed indoors and operated where no feed is produced.

FORCED MOLT

Force-molting at the end of the first laying year encourages a satisfactory rate of lay of acceptable egg quality during the following year. There are a number of ways to cause molt. One is as follows. Along with light restriction, feed and water are removed for several days. Then the water is turned on and 3 lb of grain per 100 birds are fed. In another 3 days, 6 lb of grain are fed for 3 days. After 3 days, a limited amount of mash is offered and the next day full mash for the remaining period.

Forced molting results in improved feed efficiency. The high consumption figure for the treated birds during the stress period is due to the fact that the hens cease to lay. The stress period continues up to the time the production of the treated birds equals that of the nonstressed birds. A somewhat higher egg production and lower feed conversion results in a substantial difference in egg income over feed costs in favor of the forced-molt group. Recent work indicates that if molting or induced resting is to be effective, 2 or 3 rests during a 2-yr productive flock life are needed.

RECORD KEEPING

It is difficult to make money year after year without keeping meaningful records. Only by records can a poultryman tell what kind of a job he is

doing. Is he wasting feed or breaking too many eggs? Is his help giving the birds necessary day-to-day attention? If records are not kept the reasons for poor performance cannot be pinpointed. Further, management cannot be improved because errors will not be determined.

Record forms provide spaces for recording the needed information. By keeping records and studying them to find ways to reduce costs, it is possible to increase income per dollar invested. Records should be kept on things that have to be done. Lack of meaningful goals and lack of attention to details assure failure of any operation that requires business management. Make sure goals are meaningful with respect to operation and then set out to reach them by following the old axiom, "If you take care of the little things, the big things will take care of themselves."

Types of Records

What records should be kept? The kind of records needed depends on the type of business, how it is operated, and where it is located. A started pullet grower keeps different records than an egg producer. With started pullets, your business requires records on daily growing periods, mortality during the growing period, percent of saleable pullets produced from the number of pullets started, feed used per day, and total feed used per bird, dates the birds were debeaked, vaccination records including age at which vaccines were administered and the type and lot number of vaccines, drugs used, and when and how they were administered. This information spots areas of needed improvement.

On the other hand, the egg business requires records on number of pullets housed, date housed, age at housing time, daily egg production, daily mortality, reason for mortality, culls, feed used daily, medication used and cost, and egg receipts. With this information feed conversion, percent hen-housed production, and all the other data necessary to measure the success or failure of various management practices can be estimated.

Keeping a record of the feed used on a daily basis presents somewhat of a problem, but it does not need to. Daily weighing of feed is most accurate and this method should be used whenever possible. However, alternate methods provide usable information. If a motorized cart is used for feeding, mark several levels in the cart with a tape and then weigh the cart empty and record the cart weight as it is filled to the various levels. Each day records should be kept of the full or partially filled carts of feed put in the troughs. With simple multiplication the pounds of feed used per day can be calculated. The cart should be weighed with each new batch of feed. If a poultry house contains automatic feeding equipment, the feed hopper should be marked to show various levels. Then the hopper should be filled by hand, and the feed weighed. This will indicate the weight of feed

the hopper contains when filled to the various levels. When the hopper is filled in the morning, subtract the weight of the remaining feed in the hopper from the weight of the hopper when it is full. This indicates how much feed your birds have used.

The small amount of time used in keeping records will be well spent. Management should set goals. Birds should lay 240 eggs or more in 12 months on 4.2 lb or less of feed per 1 doz eggs. Not more than 1% of the flock per month should be lost. If the birds are using more feed to produce a dozen eggs begin searching for the reason and take steps to correct the problems causing the decreased performance. By making comparisons and looking for ways to reduce feed costs, income per dollar invested can be increased.

Properly kept records will make business profitable. It gives an opportunity to size up weak points and make them strong points. Some poultry associations, hatcheries, and servicemen provide record forms as a service.

Records should be set up to give the kind of information needed to analyze the business. Eggs per hen housed, dozens of eggs to date, pounds of feed required per dozen eggs and percent livability are necessary to know. A 28-day period (4 weeks) is preferable to a monthly basis because months have different numbers of days. Egg production on a hen-day basis is different than that on a hen-housed basis. *In figuring on a hen-housed basis, the number of eggs is divided by the number of hens placed in a laying house. On the hen-day basis, the number of eggs produced is divided by the average* number of hens living during the laying period. Production figures out higher on a hen-day than a hen-housed basis, since the latter assumes no mortality while hen-day takes into consideration mortality and culling.

Egg production averages about 70%. The birds start out with 6% rate of lay at 22 weeks, and increase it at the rate of 12% a week until it is 84% at 29 weeks. The peak is 86% at 30 weeks. For the next 34 weeks it drops 0.5% per week and for the next 13 weeks at the rate of 1% per week.

A budget for the layers should be prepared to determine what the money needs are and what profits are likely to be. To figure the budget, multiply the number of dozens of eggs the layers will lay times egg production costs. The figures should be those which apply on your own farm rather than standard figures. A goal, a target to shoot at, should be set whether hatching or market eggs are produced. If properly managed either enterprise can be profitable.

CULLING

Culling provides an opportunity to save on feed costs. Close culling of pullets at housing time removes underdeveloped pullets. After the birds reach their peak of lay (95% of the pullets are laying) removal of 2 to 4%

of the birds not in lay will save on feed costs. When hens are kept 14 months, a large percentage of the birds go out of production at the 10th month of lay and are out of lay for 2 months. These birds will not be back in production long enough to pay their feed bill and should be sold. Any time production drops below 60%, there are 10 to 15% of the birds out of production.

DEBEAKING

Debeaking of pullets requires patience to do the job right and a knowledge of knowing how and when to debeak. Chick debeaking is frequently done by the hatchery at 1 day of age and cuts water and feed intake for 48 hr. During the first three days of their life chicks eat very little, relying on their yolk for nourishment. Normal water and feed consumption is drastically reduced causing a severe stress. If they are debeaked on the first day, they have two days to recover while drawing nourishment from their yolks. When housing debeaked chicks, place the waterers on boards so that they can drink without lowering their heads; make sure the water level is within easy reach. Arrange the feed and water close to the source of warmth. Preheat the water to the same temperature as the brooding room. Feed mash for the first few days. During cold weather be sure the brooding unit is preheated.

Debeaking places a stress on older pullets primarily due to the drastically reduced water and feed consumption. Water consumption is cut by 75%. Put extra feeders and waterers in the laying house and make them readily available. Fill the hopper with mash so the bird's tender beak will not bang against the bottom. Do not feed pellets the first week.

For cage operations, make the feed deeper. Debeak during the coolest part of the day. If the temperature rises aboue 80°F some birds will bleed heavily after the operation. Some poultrymen feed a tranquilizing drug for several days before debeaking. This helps keep the flock calm and minimizes the stress of handling and debeaking. Do not debeak when birds are sick. Debeaking cuts egg breakage and egg eating as well as feed wastage by 50%. It decreases blow-outs, pickouts, and cannibalism.

Because of differences in beak length and shape there is no standard slice off the beak. Each bird is debeaked in relation to the length and shape of her beak. Some poultrymen debeak when birds are between 12 and 22 weeks of age, 2 weeks prior to housing time, or at the first sign of trouble from picking. For pullets, cutting both upper and lower beaks produces the best results.

As for baby chicks, adjust the blade's heat so that it glows cherryred. Hold the bird's legs in one hand and the head in the other. Use your thumb and forefinger on the sides of the jaws to open the mouth. Place the upper

beak over the bar so that the blade strikes a point two-thirds of the distance from the tip to the nostril. Incline the head so that the cut slants from this point backwards. Leave the top of the beak about ⅛ in. longer than the lower surface. Cut the lower beak squarely at the point where the fleshy tissue ends. After the cut, roll the cut surface against the hot blade to sear the wound and round the edges of the cuticle. Debeaking does not stop picking but hampers the birds in their efforts to pick; because of this it reduces cannibalism. Retouch a bird's beak whenever necessary because the original debeaking job is almost never 100% effective.

GENETICS

There is a genetic variation in chicks with respect to arginine, lysine, and methionine utilization. Some of this is due to a difference in appetite, but when appetite was eliminated as a factor, there was still a very definite metabolic difference between high and low arginine requirement lines.

In recent years, there has been recognition of a number of metabolic abnormalities of genetic origin. Over 100 known metabolic diseases are known and more are being found all the time. There are great individual variations in the thousands of enzymes which are inherited. As these genetic abnormalities are better understood, there will be better chance of determining specifically what good nutrition is for a particular individual.

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ENVIRONMENT

The comfort of animals depends not only on the temperature but on the humidity which is one of the most important, yet least understood, aspects of comfort. In its simplest terms, relative humidity is the amount of water vapor (moisture in a gaseous form) compared with air saturated with moisture vapor at the same temperature. The quantity of water vapor the air can hold varies with temperature. A cubic yard of air at 0° F holds only half a thimbleful of water in vapor form, but if that cubic yard of air is heated to 72° F, its moisture holding ability is increased 34-fold. The reason why warm air holds more moisture than cold air has to do with the fact that air is made up of molecules which have spaces between them. Water vapor is held in these spaces. When air is cooled it contracts, the molecules move closer together and the spaces between them where water vapor is held are small. When air is warm it expands and the spaces between the molecules grow larger and more water vapor can be contained. Therefore, warm, dry air will absorb moisture from any possible source, including animals.

Effect of High Humidity

Excessively high humidity in hot weather is a source of summer discomfort because it reduces the body's ability to give off heat. One of the ways by which heat is given off is through evaporation. When the humidity is too high, the body's rate of evaporation is slowed or halted. Humidity that is too low can be just as uncomfortable as when it is too high. Overly dry weather absorbs moisture from the body drying out the throat and nose. An evaporative cooler cannot cool to a comfortable level when the weather is extremely humid. It just puts more moisture into the already soggy air, adding to the body's discomfort.

Optimum Temperature

Hens produce more eggs of highest quality around 55° F; a variation of 15° F in either direction from this optimum lowers production about 8%, and greater variations cause an accelerated rate of decline. Protection against unreasonably low temperatures is best provided by well-insulated

poultry houses equipped with suitable heating and ventilating equipment. Practical methods of affording some protection against unreasonably high temperatures include: providing shade, cool drinking water, sprinkling with water, and increasing the rate of air movement.

In rearing chicks, temperatures taken at the edge of the hover 2 in. above the floor should be 90°F to 95°F at the start, dropping at a rate of 5°F weekly for the first weeks. Room temperature should be 60°F to 75°F for the first 6 weeks. Keep chicks near hover by a guard rail placed 24 in. from the hover, widening the circle each day until the birds have the run of the entire room at the end of the week. For growing fowl, room temperatures should be between 50° and 70°F; for egg production, between 40° and 70°F with optimum tempertature at 55°F. For ducklings, hover temperature should be 90°F at starting time, decreasing to 80°F for the second, 70°F for the third, and 60°F through the fourth week.

Heat is dissipated from the birds through evaporation of moisture from the membranes of the respiratory tract. Each quart of water vaporized at body temperature removes 2,150 Btu of heat from the body. If the inhaled air is as warm as the body and the relative humidity is 100%, poultry cannot lose heat and they collapse. Hens survive air temperature of 90°F providing the relative humidity does not exceed 75%. This illustrates the importance of both temperature and humidity control. At a low temperature, humidity is not an important factor in the loss of body heat. Most of the loss of body heat is through radiation and convection. Humidity also affects the rate of evaporation of water from poultry litter. If too high, the result is wet litter. Humidity between 30 and 60% is recommended; above 60% nervousness, poor feathering, feather picking, cannibalism, and an increase of the danger of infection with parasites and microorganisms are encountered. Humidity below 30% renders membranes of the respiratory tract more susceptible to infection.

Ventilation

Rate of air movement is associated with temperature and humidity control. In the ventilation of poultry houses, the optimum rate of removal of air varies with building construction, its size, number of birds, floor space, and atmospheric conditions inside and outside the building. Chickens over 2 weeks of age can withstand air movement up to 300 fpm.

Ventilation is a major management problem in the operation of crowded poultry houses. The minimum number of square feet per bird consistent with optimum performance is intimately related to that of ventilation, humidity, temperature, and dryness of bedding and litter. When there is a wide margin between the cost of production and the selling price of the bird, a limited amount of crowding may be most profitable.

Watering

Frequency of watering is a factor in assuring proper water intake. Poultry drink small amounts at a time. Feeds are low in moisture and so birds need a constant supply of water in close proximity to the feed and with the proper allowance of drinking space. Cool drinking water is desirable in the summer rather than water from a tank that is continually heated by the hot sun. Birds on lush pasture may get almost enough water from this source alone to supply their needs and one watering per day is ample.

Lighting

Different types of colored lights have been used with equal results in rearing pullets. To guard against having light of inadequate intensity during the laying period, test it with a light meter. A high incidence of cannibalism occurs in pullets raised under white light, when not debeaked. Red, orange, and green light prevent cannibalism in White Leghorn cockerels. A pronounced eye enlargement occurs in birds placed under low intensity blue, green, and red lights; it is evident at 12 weeks of age and persists to 20 weeks. Layers given more than 18 hr of light a day helps only the electrical utility.

Pullets grown in darkness and kept that way during the laying cycle averaged 59% production whereas others that received a gradual increase of light during the laying period gave 73% production. Many experts recommend increase in light 15 min every other week up to 18 hr during the laying cycle. It is generally agreed that the length of daily light periods in the laying house should not be decreased. Using red light during the growing period and white light in the laying house produces excellent results.

The Dust Problem

The dust problem in poultry operations is of great importance. In winter, poultry houses are low in humidity and high in dust. The litter, the feed and the bird itself are sources of dust. Most dust consists of particles of fragmented feathers and tiny particles of dried skin. The type of feed is not as important as the type and age of litter. Shavings, peat moss, sawdust, and clay, in that order, are sources of dust. Reused litter is dustier than new material. There is a peak of dust concentration during midmorning and midafternoon and a gradual increase as birds get older. Birds are able to tolerate a high dust load, but it is generally believed that dust is a harmful factor. Dust has been studied from a bacteriological standpoint; it can act as a major carrier of disease-causing microorganisms in the bird.

It increases disease load in several ways: organisms are actually transported on dust particles and irritation caused by the dust lowers natural resistance of the respiratory tissues to the organism. It may also set up an allergic reaction in the respiratory tract due to the fact that it is mainly protein in nature. It increases the incidence of air sac lesions in young turkeys. High bird density and reduced ventilation produce a higher microbial contamination of the air.

To overcome the dust problem, several methods have been tried. Humidity has been increased with an air scrubber using a water spray. This reduced dust but unfortunately increased humidity which results in wet litter, which is even more of a problem. Pelleted feed that does not break into small fragments helps. However, most of the dust originates with the chicken itself. It is advised to maintain humidity as high as possible without causing wet litter. Increased ventilation helps but makes the house more difficult to heat. Improving the dust problem for the birds also makes conditions far more pleasant for the men who work with them.

Influence of Environment on Egg Quality

Hot weather and flocks that have been in production nearly a year or longer produce poor shells, mottled yolks, watery whites and eggs with off-flavors. During hot weather, feed consumption drops resulting in a decrease of calcium intake. Interior egg quality is a complicated factor, the longer and higher rate of lay, the poorer the interior egg quality. Eggs pick up odors and flavors from their environment. Musty odors, vegetables, and strong smelling disinfectants are some of the most common causes of odors. Keeping the flock comfortable will help maintain production and good egg quality. This involves ventilation and increased watering space or time the water is on. Frequent removal of the manure helps control flies.

TABLE 27.1

CHANGES IN SPACE REQUIREMENTS AND BODY WEIGHT FOR LAYING HENS

Year	Type Housing	Space per Bird		Body Weight (Lb per Bird)
		Sq Ft	Cu Ft	
1926	Floor	3	32	5
1946	Floor	3	24	4.5
1966-67	Floor	1	8	4
1966-67	Cage	0.5	4	3.7
1970	Cage	0.25	2	3.5
1980-est.	Cage	0.125	1	2.5

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MANURE

With the increased size of poultry operations, larger quantities of manure means more concentrated odors. Manure is not the only problem; henhouse odors, dust, and improper disposal of dead birds are additional factors. If proper precautions are taken, spreading manure on the land raises a minimum of objections due to odors. Humidity should be low so the material can dry quickly and it should be plowed under. Use of outdoor lagoons or stabilization ponds must have the approval of the State water pollution control agency. In cold climates, aerobic ponds sometimes go septic under ice cover and give off objectionable odors for varying periods when the ice breaks up in the spring. Pollution of ground or surface water can occur. Evaporation or seepage may be a problem and objectionable odors may develop and be hard to control. For lagoons, a large area is required, relatively well-isolated, and enclosed with a fence. Oxygen is soluble in water to the extent of 8 to 10 ppm, and sewage needs at least 10 times that amount. The air contains oxygen and more will dissolve when the original oxygen is removed by bacteria, but the dissolving process is slow and the removal rapid. Thus, oxygen often becomes a limiting factor, reducing the waste-converting capabilities of bacteria. Therefore, sewage

disposal through microbiological activity must be combined with oxygen delivery via algae.

Manure Disposal

Composting may be practical in warm, dry climates, although methods for large scale operations have not been fully developed. Dehydration of chicken manure creates a product usable as a fertilizer and soil conditioner. The material is dried to 10 to 12% moisture, so that it can be stored without heating or molding. Incineration of solid wastes is receiving greater emphasis. Most states now require air pollution control devices on incinerators. Waste disposal must be recognized and accepted as a cost of production. Some poultrymen are now marketing poultry manure and getting a portion of the cost of cleaning and hauling returned to them. Those in the business of producing eggs must give major consideration to public relations and public health by having a good appearance and avoiding nuisance conditions.

Composition of Manure

Poultry wastes and litter as animal feed have been condemned by the Food and Drug Administration mainly because of possible disease transmission. But birds on the floor are exposed to poultry wastes and consume them to some extent. Broiler litter and hen manure are different. Hen manure collected under cages is "pure quill," containing only voided feces. Fresh manure contains from 12½ to 35% crude protein, with most of the nitrogen being tied up as uric acid and ammonium salts. In fact, from 65 to 90% of the nitrogen in poultry wastes or poultry litter is nonprotein nitrogen which is of little value to monogastric animals such as chickens, although under certain conditions, some may be used.

Utilization of Poultry Litter

In fattening trials of beef cattle in Virginia, 25% unprocessed poultry litter was fed in contrast with conventional fattening rations. The feed efficiency was in favor of the litter feeding. Canadian workers have also shown that poultry waste is of some benefit as a feed. They found that poultry waste products are low in energy and probably not suited to fattening rations. Poultry litter silage has been fed directly to steers. There are some other problems with feeding poultry wastes to cattle. High moisture causes spoilage. Although the protein is adequate for cattle, availability of calcium and phosphorus is questionable. Vitamins A and D are almost negligible in poultry wastes. Nitrate and nitrite levels are well below levels for use in beef cattle rations. The primary place for poultry wastes for beef cattle appears to be in maintenance rations. Main problems with the use of poultry waste products are possible disease transfer, drug residues, and salmonellae.

Dried Manure

If cleaned out daily, manure from hens in cages runs between 70 and 75% moisture. If allowed to stand for 6 months, the moisture disappears into the air and it becomes considerably drier, about 5.44%. Fiber is about 12% in fresh manure. Crude protein ran in one experiment from 16 to 20%, although there are reports that it can go as high as 35%; true protein is 10 to 11%. These chemical analyses show the protein nitrogen level to be rather low, and thus not suitable for a protein replacement as far as chickens are concerned. A machine has been developed which can dry poultry wastes quite successfully. It works on a very simple process. The waste product enters through a trough with a series of baffle plates. A hammer mill is in a dump below. The waste material comes in the top and a gas burner shoots hot gases in at the bottom. The manure is shaken down towards the hammer mill which chops and returns the material for further drying. Soon it is dried and is blown into a tank. It takes about 45 sec to become dry. The final product smells similar to cow feed and is greenish in color. When moisture is put back into it, it does not smell like poultry manure. It has a rather pleasant aroma and contains 23 to 33% crude protein. The reason for this variation is that the longer the manure is allowed to remain under the cages exposed to the air, the more nitrogen is lost. Calcium varies from 9 to 11% in caged layer manure. Phosphorus is about 2.8%. The moisture of the dried product is about 7.5%. The dryer running 6 to 8 hr a day dried manure from 20,000 layers for about $3.00.

Feeding of Dried Manure.—A series of chick feeding trials has been run using this product. The first with Leghorn chicks contained 0, 5, 10, and 20% of dried fecal product. The manure was incorporated in the ration at the expense of corn and some soy. Weights at four weeks were not statistically different. Feed conversion was 2.39, 2.47, 2.47, and 2.62. This waste product is rather low in energy because even 5% causes a reduction in feed conversion. In another trial, 0, 10, 20, and 20% + 5% fat was used. Weights were 605.4, 568.9, 571.4, and 623.4 gm, respectively. Feed conversions were 1.82, 1.94, 2.05, and 1.94.

There is no specific law against shipping dried manure interstate. Hence, even if the government comes out with a regulation, it does not necessarily mean that it will never change its position. This happened recently in the matter of fish flour, made from whole fish. The Food and Drug Administration would not permit it to be sold for human food because they thought people would not accept a product that had the guts of the fish in it. But the government changed its position and allowed fish flour to be sold because when it is dried disease factors are eliminated.

Heating to 750° to 800°F destroys disease and other microorganisms. If this material is passed through animals indefinitely, however, there would be a buildup in concentration of drugs.

Removal of droppings is a problem on battery farms. Depending on the type of hen, housing, feed and extent of water supply, the production of droppings is from 140 to 180 gm per bird per day, or as much as 64 kg per hen per year. One thousand hens produce 100 cu m of droppings and water per year. A ton of droppings per day with a moisture content of 70% is produced by 5,700 hens. More than twice the amount of water must be added to the droppings as the hens themselves have done for removal from the house. In tier batteries, removal is done with scrapers and droppings are gathered at one point. In the flat deck or stair batteries, it is collected in the gutter where it is left for sometime if the gutter is large enough. The droppings can also be flushed with water and collected in a pit which is emptied several times a year.

Cost of Drying.—The investment for drying is fairly high and a commercial selling organization may be required. Although the dry droppings can be fed to cows, there is not yet a consensus regarding their value as a feedstuff. They contain a high level of uric acid which can be used by ruminants. The level of minerals, especially phosphorus and some trace minerals, is high. In spite of certain favorable properties, it seems doubtful whether the use of poultry droppings for feeding purposes will assume large proportions in the immediate future. More work needs to be done to determine the real feeding value of poultry droppings.

Fertilizer Value of Poultry Manure

Poultry droppings make very good fertilizer. They contain more plant food than cow or pig manure. Nevertheless, poultrymen find difficulty in disposing of droppings. Poultry manure could well be used as a medium for the raising of some types of insect larvae which, in turn, could be harvested as a feed material. Larvae also lack something in regard to esthetic value, but they would have a very high nutritive value, since larvae of most insects are quite high in fat and protein.

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STRESS, BAD HABITS, AND VICES

Life in a cage in a battery is unnatural for the hen; she can move freely but cannot supplement her feed. Caged birds are constantly in some stress—even if feeding and management are excellent. Little attention is paid to individual birds, although regular checkups are made. Diseases, behavioral abnormalities, and vices are checked for, as well as the consumption of the feed and drinking water.

Mechanization is only good if the bird is seen not as a machine but as a living being. Since most layers placed in the batteries are reared on litter, special attention should be paid to the prevention of coccidiosis and gastrointestinal parasites. Place birds into battery cages at 18 to 20 weeks of age so the birds can get accustomed to the new housing before laying starts and can be wormed if required. Battery fatigue is less frequent in birds that have been in battery cages from an early age than in birds placed in them when older.

The vicious habit of picking feathers, combs, wings, toes, tails, vents, and other parts of the body is one of the serious problems in raising poultry. It is prevalent among chicks, growing pullets, and mature birds and leads to outbreaks of cannibalism if not promptly controlled.

An English *Complete Poultry Book* published some 80 yr ago refers to feather picking as a pernicious habit and suggests the chopping block is the surest remedy. It also suggests a wire bit to prevent shutting of the beak firmly together so the birds are unable to grasp feathers. Dark nests tend to keep hens on the roosts until the vent has returned to its normal position. This takes away the temptation to start pecking.

Cause of Bad Habits

Bad habits are usually attributed to faulty management, including overcrowding, overheating, underventilation, high humidity, too bright light, insufficient nesting, eating and drinking space, presence of injured or sick birds, and housing together of pullets of different ages. Other factors al-

leged to cause cannibalism are: temperature too high in the brooding period, lack of fresh air, crowding, allowing birds to be without feed for considerable time, insufficient feeding and watering space, and insufficient and poorly designed nests. From the standpoint of nutrition, a deficiency of any essential nutrient results in a depraved appetite that could lead to cannibalism. Nutritional preventives suggested are: feeding of heavy whole oats, grass clippings, alfalfa hay, addition of more salt to the mash or to the drinking water, and reduction of the amount of scratch grains. The breed of chicken is also important. Most of the difficulty reported has been with White Leghorns which have a disposition and temperament quite different from the heavier breeds.

To a lesser extent vices are also attributed to rations deficient in certain nutrients or containing too much of others. Too little protein, fiber, salt, and bulk, and too much corn in the ration have been advanced as causes of vices. Large amounts of yellow corn in rations are said to favor the formation of oily, curly, or rough feathers; whereas, oats, oat hulls, and wheat bran in rations produce smooth and glossy feathers. It is assumed that birds are prone to pick at rough feathers rather than at smooth ones and that feather picking is a prelude to cannibalism.

The complex nature of cannibalism and feather picking is conceded by those who have made a study of the subject. Whereas, the opinion prevails that nutrition is secondary to management as a cause of vices, it is recognized that inadequate rations produce syndromes which do not favor the contentment of the bird.

Cannibalism

Poultry of all kinds may become cannibalistic when confined. Breeding may influence slowness of feathering which combined with faulty management may encourage picking. When quills are picked and broken the pigment spreads out under the skin giving a bluish appearance. Prolapses of the oviduct may be a contributing factor. The oviduct becomes open to view and is picked by other layers. This causes pickouts. If the birds after laying an egg do not remain in the nest until the everted cloacal membrane is withdrawn, the other birds are attracted by the red membrane and begin picking it. Sometimes the oviduct may become loose and protrude from the vent when the bird lays an egg. The blood which accompanies the prolapse and the oviduct itself attract other birds and the injured one is picked to death unless promptly isolated. The trouble is most common during late winter or early spring. Internal rupture of the oviduct may result from severe inflammation, an attempt to pass large eggs, or from injury. The breaking up of the oviduct permits yolks or fully formed eggs to pass into the body cavity. The yolks may rupture and the contents dry out

causing a yellow coating over the viscera. There is no treatment for rupture of the oviduct. Egg bound troubles occur most frequently among pullets. It results from the attempt to pass large or double yolked eggs through an oviduct that is too small for their passage. Birds appear listless and make frequent attempts to lay.

Research on social behavior of the domestic fowl, especially chickens, indicates the complexity of events. Social interactions differ in frequency and vigor as they function with age. Picking increases from hatching to about ten weeks, after which age data are not available. The amount of past social experience in groups accounts for differences between age groups. The more the social experience, particularly in changing social groups, the faster and more vigorous the organization processes. The organization of social groups within the pen is essentially linear. That is, alpha birds peck all the others; the beta birds peck all under them, and so on. The weight of birds and their status and social order usually bear an inverse relationship to each other. From a management standpoint, preventives of cannibalism include some of the following: provide more floor space, supply ample feed and watering space for rapid growth and egg production, feed scratch in the litter to layers morning and evening to keep the layers busy, and stir the litter. Crowding is relieved where pullets or stock are removed to the range as soon as age and weather permit. Cool room brooding is helpful in combating cannibalism. Brooding rooms can be cooled rapidly if poultry buildings are designed to allow cross ventilation.

Prevention of Picking

Devices are available for the prevention of picking among laying chickens. One type prevents the bird from seeing downward; the second type is a blinder which prevents the birds seeing straight ahead. These devices do not affect adversely either feed consumption or egg production. Bits are used successfully to prevent turkeys from picking. The wire keeps beaks apart so they cannot be shut tightly and injure other turkeys by picking.

Debeaking is the most reliable method for controlling cannibalism. Debeaking may be done with only a slight or no drop in egg production. Debeaked birds have difficulty in cleaning up mash in hoppers, so at least ½ in. of mash should be kept in the hoppers. If scratch grain is fed, it should be fed on top of the mash in the hopper. About six months is required for the beak to grow back. Desnooding turkey poults is also practiced. Some growers cut off the snood at about four weeks of age, but it can be done at day old easier with no discomfort to the poults. Chickens may be debeaked as early as three weeks of age. It actually improves the performance of the flock. Prompt and sometimes drastic action is necessary to avoid serious losses.

Cannibalism occurs more often among white than colored chicks and is manifested first by toe picking, tail picking, or feather pulling. This may be due to the fact that blood shows more plainly through the quills of white feathers. Darkening the room and painting the windows with a ruby-water color paint are helpful in preventing cannibalism. Cannibalism usually disappears as soon as the chicks are given fresh grains. In the case of adult birds, cannibalism, and kindred troubles develop as a habit, usually in birds in close confinement. Suggestions for preventing it include use of anti-picking devices before the birds begin to lay and debeaking losses occur in numbers. Debeaking will stop the vicious habit for at least three months. Pickouts are usually encountered among pullets. Inspection of the flock for ringleaders and removing them from the flock, as well as removing injured birds in pens are helpful. Smearing the affected parts with quinine and red paint has been used. Some farm flocks experience little cannibalism; in others, it is a major source of mortality . . . as much as 30% in some instances. Perhaps through selective breeding some cannibalism may be eliminated.

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Feed Manufacturing

PURCHASE, RECEIPT AND STORAGE OF SUPPLIES

Grains are purchased from the grower on the market basis and received usually in medium-sized truckloads. Storage is generally in bulk of the whole, unprocessed grain. Many feed grains store satisfactorily, but precautions should be taken to prevent unpalatable or moldy feeds. Grain storers may find themselves involved in "grain banking." This is the practice of holding a customer's feed grains co-mingled with others at a standard quality for future processing and return in finished feeds. The law requires that your grain bank position be covered at all times with appropriate grains. If you hold a franchise from a large supplier, most of this material comes by truck or rail car in bulk or bags as the trade requires.

Most feed mills effectively use the services of feed brokers and jobbers. Long term contracts are obtained at a favorable rate. In storage, there should be common sense protection from insects, rodents, and weather, as well as proper stock rotation. Segregated storage of microingredients is important to facilitate accountability and to protect the material from contamination. Testing of microingredients is costly, so most mills rely on suppliers of drugs and ingredients who should be impeccably reliable. Some smaller mills custom mix ingredients, and thus must provide holding and storage bins for this business. There may be 10 storage bins for assorted supplements and 4 to accommodate custom work. Although bulk delivery is on the increase, there are efficient and attractive "on the farm" forms of processing where the sale of bag concentrates and premixes is a highly lucrative business.

Credit is important in sales of feeds. The cost of money has been too well proved to ignore when making sales. There should be an advantage to the customer who meets terms and a penalty for those who do not.

MARKETING GRAIN THROUGH A GRAIN EXCHANGE

The grain exchange is a public marketplace where grain supply and demand meet . . . where processors, storage elevator operators, and exporters go to purchase the farmers' grain. Its trading activities are governed by rules and regulations of the exchange itself and it is licensed by the U.S. Dept. of Agr. It does not buy or sell grain and in no way sets prices. There are exchanges in: Chicago in the Corn Belt, Minneapolis in the spring wheat country, and Kansas City in the winter wheat-producing

Courtesy of Grain Exchange, Chicago, Ill.

FIG. 28 1 GRAIN EXCHANGE IN CHICAGO WHICH PROVIDES A CASH MARKET AND FUTURES MARKET

The grain exchange is a marketplace where supply and demand for grains meet It is licensed by the U S Dept Agr., and governed by definite rules and regulations.

area. Exchanges are also located at St. Louis, Omaha, Toledo, Peoria, Indianapolis, and other places.

Commercial marketing of grains begins at the country elevators which accumulate grain supplies from farmers and assemble carlot shipments. Grain is shipped to the terminal markets in care of an exchange member. His job is to see that the car of grain is sold to the highest bidder and for this service he receives a commission set by the exchange. In some exchanges, there are two markets: the cash market and the futures market. The cash grain receiver sells to processors, terminal elevator operators, and exporters. Processors buy for their own needs which may be flour, cereal, or feed. Terminal elevators are reservoirs of the grain trade which buy the surplus for storage and distribution at a later date. Exporters buy for the foreign trade.

Futures Market Trading

Futures market trading is a method of buying and selling grain in specified quantities for delivery at a later date. It is conducted in trading pits at

the exchange, one for each kind of grain handled. Sellers and buyers shout out their offers and bids and at the same time signal with their hands both the number of bushels offered or bid, and the price. Delivery months commonly are July, September, December, March, and May. In July, winter wheat crops are moved to market. In May, there is a cleanup of the old crop.

Prices are arrived at through open, competitive bidding; daily price fluctuations are a reflection of changing supply and demand. Supply is influenced by the weather, plant and insect diseases, drouth, floods and many other forces. Demand is influenced by government support and loan programs, the level of export movements, the flour demand by bakers, seasonal activity, and war.

Hedging

Hedging is a grain term which means price insurance. Millers, country elevator operators, processors, merchandisers, and exporters of grain can protect themselves through hedging against price risk and thus operate on narrower margins of profit. To hedge, a man does two things at once. He operates in both the cash and futures market at the same time, but in opposite directions. If he buys X bushels of cash wheat, he sells X bushels of futures wheat. When he sells the feed or flour he makes from X bushels of wheat, he then buys X bushels of futures wheat. Selling the feed or flour cancels the cash deal, and buying the futures wheat cancels the futures contract.

In the meantime, any rise or decline is automatically taken care of, and the miller knows when he buys the grains what he will have to charge for his product to break even. Without hedging, he could not foretell what the price is until he is ready to sell. The above example is what may be called a "perfect" hedge. This cannot always be accomplished just as insurance of any kind does not always afford 100% protection. Actually, the hedging transactions are rather complex business operations, and the example given here is only intended to illustrate the fundamentals of hedging.

The futures markets serve both producers and consumers of grain. From the point of view of the farmer, this system means a year-round market, available price information, and low middlemen costs. Hedging is only possible in a speculative futures market. A speculator performs a very important function in grain marketing and makes hedging possible. The speculator is a professional risk taker who takes price risks in the hopes of making himself a profit. Thus, many different business operations are involved in bringing grain from the farm to the table in the form of cereal or bacon and eggs.

Factors Affecting Prices of Grain

Factors which affect the price of grain on any particular day are: the marketings, carryover, prospects for next year's crop, and competition between ingredients and companies. The demand reflects the requirement of millers, maltsters, feed manufacturers, processors, stock feeders, and the export market. The export market is a function of commercial demand and government programs. War and peace rumors, government programs such as price support and acreage allotments all influence supply and demand. Price supports tend to draw prices towards the support level.

Exchange Operations

Thus, the grain exchanges maintain a market where buyers and sellers of grain meet and carry on their business. Membership is made up of members of all phases of the grain business who follow the same rules and code of ethics to maintain membership. It is governed by 15 directors, a president, and 2 vice presidents who serve without pay.

Trading in commodity markets is done by outsiders whose callings range all the way from professional speculators to housewives who hope to make a killing on a small investment. Buying a commodity in the futures market is obligating yourself to accept delivery of a certain quantity at an agreed-upon price at some particular time in the future. You deposit "earnest" money with your broker and promise to accept delivery. You do not pay for it until the commodity is actually delivered. Your broker sends your order to a broker on the floor of the exchange who buys the lot from another broker who has a client who wants to sell. The price is hammered out in the open in back-and-forth bidding. A clearing house of member firms as-

TABLE 28.1

FACTORS AFFECTING PRICES OF GRAIN IN THE UNITED STATES

Supply	Demand
(1) Carryover of stocks	(1) Domestic
(A) Government	(A) Processors
(B) Nongovernment	(B) Livestock producers
(2) Production	(C) Storage operators
(A) Amounts placed under loan	(D) Speculative demand
(B) "Free" production	(E) Other
	(2) Export
Other (Related to Supply and Demand)	(A) Production in major exporting and importing countries
(1) Government loan rate	(B) Processors
(2) CCC sales policy	(C) Livestock producers
(3) Government and private estimates and forecasts	(D) Storage
(4) Hedging pressure and trading systems of speculators (futures markets are directly involved but they affect cash also)	(E) Speculation
(5) War scares	(F) Food for peace authorization
(6) Other	(G) Trade regulations
	(H) International trade agreements
	(I) Other

sociated with each exchange guarantees that buyers and sellers will perform their obligations.

A peculiar aspect of the futures contract made by the buyer and seller is that they are rarely fulfilled. The last thing the buyer wants is grain and the seller generally has no intention of delivering any grain in the first place. Only a very small percentage of commodity futures deals are ever consummated by a transfer of the product itself. Only a few traders in the market actually want to accept or make delivery of the grain at the agreed-upon price. They can do so by not offsetting their original buy or sell order. They will pay or be paid for the grain when it is delivered.

To the outsider, commodity futures seem to be nothing more than an elaborate guessing game. They are, but they also serve certain marketing functions, chiefly by providing firm supplies of grains and a means of protecting against unfavorable price changes. Hedging operations have the aim of protecting the businessman against adverse price changes. There are standard contracts as to size for each commodity. For example, corn is traded in units of 5,000 bu of No. 2 yellow corn. Other prescribed grades can be delivered against the contract at fixed premiums and discounts on the standard grade.

Commodity futures trading is a thrilling and sometimes profitable game, but there are drawbacks. An outsider who has no inventories to hedge would participate in the market as a speculator. Commodity futures react to innumerable forces. Unlike a security, a futures contract cannot be salted away in a safety deposit box. There are markets in about 30 commodities, all the way from butter to zinc. From the standpoint of feeds and feeding, there are markets in corn, oats, barley, grain sorghums, wheat, rye, soybeans, fishmeal, and soybean meal.

FEED MANUFACTURING IS A HIGHLY SPECIALIZED BUSINESS

Feed manufacturing has been an industry for many years and has expanded in considerable volume over the years. It has been in competition with home or farm mixing of feeds from the beginning. Feeders should put their best efforts where they can make the most profit. Poultrymen, for instance, can use their time to know their stock better and thus do a better job of feeding their animals. Their time is more valuable doing the latter than mixing feeds which the feed industry does at low cost. Thrifty housewives no longer weave cloth to produce a dress. Their time is more valuable making the dress. It is the same thing with home-mixing feed ingredients. Competition in poultry production is so great that maximum results must be attained for the time and money spent.

About a decade ago, the volume of formula feeds was 35 million tons annually. Now, it is 45 million tons. Twenty-five years ago, it took 14 lb of feed

and 16 weeks to produce a 3-lb broiler. Today, it takes 8 to 9 lb of feed and less than 9 weeks. Then, a ton of laying mash produced 3,300 eggs; now it is over 4,200 eggs. These efficiencies, of course, have developed because of advances made in nutrition, breeding, management, and medicants. Not much would be gained if the geneticist produced a very efficient bird, but feeds were inefficient, and vice versa. Both have to be upgraded, otherwise, there would be no benefit. The feed industry controls millions of birds in their testing programs. They do practical field testing to insure the quality of their feeds. About 40% of feed consumed by animals in the United States is formula feeds. Twenty-five years ago it was half that amount.

There are about 6,000 feed manufacturers in the United States. Allied to the feed manufacturers are many businesses which serve these companies. They work with and are considered a part of the feed industry. Examples of these are the drug people who make coccidiostats; the chemical companies who produce vitamins, amino acids, and other components; and the quarries that produce limestone and phosphate. They all sell their ingredients to the feed companies for incorporation into feeds. The feed industry is a dynamic industry and has been growing tremendously as the U.S. population has grown and feeders were sold on the convenience and economy of using formula feeds.

A worthwhile scientific publication is *Nutrient Requirements of Poultry* which is the guideline of feed compounding. A committee of nutritionists from universities and industry produces this publication under the sponsorship of the National Research Council (NRC), a quasi U.S. government agency. NRC gives the percentage or amount of each nutrient needed in various feeds. It lists nutrients needed by time or stage of life. The bulletin is revised from time to time and contains the best estimates of what is needed.

However, if a feed manufacturer compounded a feed according to NRC recommendations and then let the feed stand on a shelf of a retailer, it would not meet requirements. Oxidation of some components occurs. Then, if the feed inspector came around and took a sample, the chances are that it would not come up to guarantee. Consequently, higher levels than minimum requirement are ordinarily used. Also, just because an animal lives does not mean that it thrives, so most feed manufacturers put in their feeds more than NRC values so that if their feed is checked, it passes inspection. It is not too expensive to add extra amounts of certain vitamins and minerals; thus, it makes sense to have some margin of safety.

Leading Feed Manufacturers

Ralston Purina Company which pioneered the production of commercial animal feeds in 1894 remains the largest manufacturer in the industry, ac-

counting for about 10–11% of the domestic output or five million tons in 1960. It is about four times the size of the next largest manufacturer. Eastern States Farmers and Grange League Federation (GLF) both former farmer cooperatives have now combined as Agway and provide feeds to the member feeders in New England, New York, and Pennsylvania. Central Soya with production of over a million tons entered the feed business as a way of utilizing soybean by-products. Their production is chiefly concentrates but it also has a large, complete feed business. Allied Mills has a slightly larger tonnage than Central Soya, mainly in complete feeds. Next in terms of output below the million ton mark are Quaker Oats, Pillsbury, and Cargill. Of these major companies, manufactured feed is the major product of Purina and Allied Mills. Two other cooperatives, Western Farmer and Southern States, are also major factors. More than 2,000 local and regional companies divide up the remaining ⅔ of the total feed volume.

The structure of the feed industry has been undergoing marked changes. The earliest feed mills were situated adjacent to water transportation so that the grain and other feed ingredients could be shipped in and finished feeds shipped out cheaply and efficiently. These large terminal mills, putting through large volumes of standard complete formulations, often ship feeds hundreds of miles to markets. Since World War II, however, the rise of low cost, reliable truck transportation has changed the economics of terminal mills drastically. The markets for feed remain dispersed throughout the country. Today, ingredients are usually shipped from diverse points to a mill located close to its own market. Especially in grain surplus areas, it is senseless to ship grain to a central mill and then back to a local feed mill. Equipment of smaller size and cost became necessary for numerous local mills to replace the larger terminal mills.

RESEARCH AND FEED MANUFACTURING

For many years much basic feed research has been conducted by universities, the U.S. Dept. of Agr., and larger feed manufacturers. Smaller mills have had access to new developments in feed technology at public expense. The increasing size of farm units has also affected the structure of the feed industry. These larger units have brought about less reliance on the services of the feed dealer. The large feeder may have his own formula, mixing equipment, and storage capacity. This feeder generally buys concentrates to his specification on a price basis. As a result, small feed dealers have less economic function to perform. In many cases, they have been replaced by direct sales from larger manufacturers. The large feed mills committed to dealer programs have lost out to direct sales from local millers. The larger feeders purchase in bulk form and thus, the merchandising value of the trademark is reduced. Finally, some producing units

have become so large that they can completely support captive feed mill operations.

This movement towards complete integration reflects all the factors leading to decentralized local milling plus the cost price squeeze in commercial broilers which has moved this business in particular toward a single profit rather than split the profits in feed manufacture, hatching, breeding, growing, processing and marketing. The margin which a prepared feed can command over input ingredients is determined by the margin of end product value over feeding ingredients. The larger units of the feed industry continue to enjoy a number of competitive advantages over the local and regional mills. In the agricultural areas which have undergone less dynamic changes than poultry in the last decade, these advantages have resulted in rather stable market conditions. Even in commercial poultry, the larger manufacturers have maintained some share of the market by capitalizing on these advantages. The larger feed mills with large grain merchandising activities and volume of commodity handling are in a position to purchase ingredients more advantageously than local or integrated mills buying for a single location.

Role of Large Feed Manufacturers

Larger feed firms have also greater opportunity to substitute feedstuffs according to changing market prices. Since they are engaged in applying new research findings to practical feeding operations, much effort is directed to finding the best combinations of ingredients for each feeding operation. Feed mills with little or no facilities for testing mix to customer specifications put out untested products. These mills may overcome the research deficiency simply by overformulating, that is, putting in more of certain critical ingredients than is called for by requirements. Overformulating is expensive. Both formulation and manufacture of feeds have become increasingly complex. Formulae of some feeds now call for 40 or more ingredients in carefully controlled proportions. This complexity has benefited those with technical knowledge to substitute ingredients in response to price and quality changes without changing nutritional results. For example, corn begins to lose vitamin A after about six months in storage. Proper inspection and testing can detect this loss and substitutes can be used to rectify the loss in vitamin A content.

For some of today's feeds, it is necessary to mix as little as a thimbleful of some substances to a ton of feed. Assuring uniform distribution calls for special equipment and know-how. Increase in size of farm units in order to remain competitive requires large amounts of outside capital. These financial needs have been met by traditional sources: commercial banks, government sources, and feed manufacturers. Credit expansions, partic-

ularly in poultry, reached their peak in 1958. Here again, the larger feed manufacturers through their dealers have been in a better position to offer credit to feeders. Credit has been extended for farm mixing and bulk handling equipment in return for guaranteed purchase of the manufacturers concentrate. Ironically, feed manufacturers have been pushed by competitive pressure to finance the very things which compete with their business.

Customer Service Facilities

The research and veterinary facilities of feed manufacturers are available to their customers. Of increasing importance, the feed manufacturers financial and operating talents are available for counseling. Beyond the practical benefits of the manufacturers experience and resources is the status achieved by the feeder who feels free to call on top corporate executives. Larger feed manufacturers, however, have been slow to decentralize and to make direct sales because of commitments to independent dealer organizations, and because this would place the manufacturer in competition with customers. In fact, however, large manufacturers have moved in all directions in recent years in order to protect their markets. This has contributed to overcapacity in the industry, particularly in the commercial poultry areas of the Southeast and South Atlantic.

Role of Federal Government

The Federal government has played a major role in agriculture since the early 1930's. Its activity has centered primarily on controls for wheat and other food crops, and less stringent control programs for corn and other feed crops. Production control and acreage restriction have been extended to corn and legislation has been passed that would permit extension of production controls to turkeys. Production controls are based on voluntary "participation" elected directly by the farmers involved. The government in 1968 dumped corn in the midst of the corn harvest. This was interpreted by trade observers as a means of disciplining farmers who did not sign up for restricted corn acreage. The commercial broiler industry has had recurring problems of oversupply and prices below cost. Integration has been an effort by feed manufacturers to preserve a share of the poultry feed market. The problem of overproduction results from the ease of entry which would make monopoly restrictions impossible. The trend toward increasing controls is vigorously opposed by feed manufacturers as a hard, cold business proposition. There is reason to believe that controls would actually benefit the feed manufacturer. The ultimate objective of agricultural controls is a redistribution of income in favor of the farmer. One of the by-products is to widen the margin of agricultural products. The

prices produce wider profits; the profitability of manufactured feeds would improve proportionately.

The traditional market of large manufacturers has been small or medium-sized farmers who buy feeds on service and programs, as well as on the price. Activities to benefit independent feed dealers, who have suffered from the trend towards integration and direct selling, would benefit large feed manufacturers. Of course, the feed industry is only a part of total animal agriculture. Problems of oversupply and talk of government control are not new in agriculture. Possibly the government will attempt to stabilize these animal products. If it succeeds, there is a strong chance that controls may spread to the remainder of agriculture.

Feed is one of the major costs of poultry production because poultry are fed largely on concentrate feeds which are more costly than roughages. Feed grown on the farm is not relished in raw state by man in the United States. This feed is fed to animals to supply refined products suitable for human consumption, such as poultry meat and eggs, and their products. The problem of the feed manufacturer is to determine how to utilize the largest amount of home-grown products, properly balanced, with manufactured concentrates to produce human foods economically.

Need for Nutritional Knowledge

Nutritional science has taken much of the uncertainty out of this so that feeds are now formulated that produce economical gains. Feed manufacturers realize it takes quality ingredients to make good feeds. Often the feeders use them as a base for mixing of other preparations which are cheaper in dollars per ton. He may simply dilute the feed with other cheaper feeds with no knowledge of the resultant mixture, except that the cost per ton is reduced. Probably the efficiency will be reduced also. Two-thirds of the ingredients used by the feed manufacturers are by-products of agriculture. The feed manufacturing business uses these by-products in feed manufacture and thus helps to keep their price high and stabilize the income at the farm level. More knowledge of the nutritive requirements of animals is permitting manufacturers to blend their feeds more accurately to furnish supplements that go with the feed produced on the farm and give poultry more complete rations.

Feed manufacturers have employed nutritionists to continue nutritional research conducted in many experiment stations, agricultural colleges, and universities. Such basic research work is necessary for continued prosperity of farmers and feed manufacturers. Because of the high standards set by the feed industry, better rations than ever before have resulted. More and more farmers are learning about the benefits of commercially mixed feeds. Some milestones in the application of basic nutritional knowledge to prac-

tical feeds are the development and use of riboflavin, vitamins A and D in concentrated dry or synthetic form, and the use of alfalfa leaf meal of very high carotene content. Of great practical importance was the application of high energy feeds to poultry. In natural feedstuffs much of the carbohydrate is tied up in nonavailable pentosans and lignins associated with fiber which lowers the efficiency. Other applications of research findings by the feed industry have been granulated and pelleted mashes, new and better systems of feeding, management, and disease prevention. Another application of great importance was the use of vitamin B_{12} to replace earlier "animal protein" and "cow manure" factors. Vitamin B_{12} was extremely important because it helped eliminate some factors which were previously unidentified but essential for proper hatchability of eggs. These factors were supplied previously by fishmeal, fish solubles, meat scraps, and even built-up litter.

The rations of the future will make greater use of synthetics and special concentrates of vitamins and amino acids. Grains providing low cost energy and the lowest cost protein concentrates will be used. Farmers will increasingly buy commercially mixed feeds and the universities will continue to do basic research and recommend feeds which allow the farmer to make the most money out of every pound of poultry meat and every dozen of eggs. The feed industry is dedicated to keep pace with nutritional research and to retain its high standards of the past.

Some experiences of the past can point out the path of future nutritional progress. One feed company used 29 ingredients and manufactured 4 feeds in 1947. Today, this firm uses 63 ingredients and markets 20 different products. Thirty-five years ago the production of soybean meal and dehydrated alfalfa were infant industries, today they are giants. Many new and unusual feed ingredients are on the horizon.

Ideas on the Future

Many of the standard ingredients will either be improved and standardized or their use in feeds will gradually diminish. Water-soluble vitamins and antibiotic mixtures, possibly added to the drinking water may be used. The standard antibiotics, penicillin, aureomycin, terramycin, bacitracin, will be used at new and varied levels for different classes of poultry. New antibiotics will also be used. Tomorrow's rations will contain added drugs, hormones and unknown growth factors. To obtain more efficient feed conversion, greater concentrations of certain nutrients within each pound of feed are needed.

Laboratory control will become more thorough due to development of faster and more precise analytical methods. Quality control will be speeded up and moved from the laboratory closer to mixing lines. Feed companies

will be staffed by more specialists. Dated feeds stressing freshness are on the horizon. Radioactive tracers will check thoroughness of mixing of feed.

Specialization of Poultry Industry

Although the feed industry has come of age, indications point to the development of even more efficient labor-saving feeds. While almost everything else has gone up in price, poultry has become steadily cheaper, tastier, and more nutritious. For example, broilers averaged 78c per lb retail in 1948; today they are 28c. In fact, most farmers can now buy chicken at the supermarket more cheaply than they can raise it. Poultrymen have moved their birds off the land into chicken cities with populations that reach a million or more. In what amounts to automated mass production, chickens peck away at computer-selected feeds which their digestive system convert into eggs and meat. One kind of chicken produces table eggs; another produces broiler or fryer meat. They are both most likely to be white in color. The egg-type hen weighs only about 4 lb and never sees a rooster. The meat-type breeder hen weighs 6 to 8 lb and shares a rooster with 10 to 14 other hens. Mass production of eggs began slowly just after World War II and has been picking up speed ever since. Today's chicken coop can be six stories high and look much like a modern apartment house. A total of 70,000 hens make their residence in one coop, living in wire cages with inclined floors. Moving chains carry food to them. Their droppings fall through the wire and are removed periodically by mechanical scrapers. Temperature and climate controls keep the coop dry; the air is free of flies, and sweet smelling. Controlled environment is the main thing. The chickens are bathed in rose-colored light found in cocktail lounges.

In California, there is a coop complex which has 1,600,000 hens. Eggs bring in $25,000 a day and it might be noted hens work 7 days a week. Manure brings in $6,000 a month. A nutritionist varies the menu according to the hen's age and the weather and chemists analyze each lot of feeds. Veterinarians autopsy every bird that dies before its time; laboratory technicians perform blood tests to make sure that the inoculation given the chickens continues to provide immunity. Statisticians keep a count of every coop's production.

What this all means is that even the smallest chicken farmer today has to operate like the big ones or be driven out of business by low prices. A small flock now runs from 12,000 to 15,000 birds. Its owner gets necessary professional services by contracting for them with one of the larger commercial feed companies.

Complexity of Feeds

Modern feeds are so complex that a computer is used to determine the most economical way of preparing them. Chicks are separated into separate sexes at hatching time at a very low cost. Thus, the poultry industry has

come to be very specialized because there is simply too much to know for anyone to know it all. Eggs may be fertilized on one farm and hatched elsewhere in incubators holding 50,000 eggs at once. Chicks may travel to a destination determined by the particular job it has been bred to do. Some farmers raise chicks into pullets; another pullets into layers; still others produce eggs. Some specialize in breeding females to be fertilized by roosters from breeders who specialize in broilers. United States breeders have put the American chicken all over the globe. Chicken, which formerly was a festive bird served for Sunday dinner, is now a bird that is cheaper than hamburger and almost as commonly eaten. Poultry scientists are confident that nature has put into the bird more than they have been able to bring out yet. Poultry production is distributed throughout the United States, but is concentrated more in areas of surplus grain near concentrated centers of population.

Better methods of preparation and packaging, fast freezing, and improvements in marketing methods have given the consumer a better product in a more convenient form. Lower prices from improved efficiency of production greatly stimulates consumption of poultry products.

Turkey production also has become highly specialized—10% of all farms raising turkeys market 90% of the crop. Turkeys are well adapted to intensive production and are produced near large centers of population.

Egg production per bird during 1925 was 93, and 143 in 1950. As egg production per bird goes up, the cost per dozen of eggs goes down. Thus, increased efficiency has made eggs a better buy for consumers and increased consumption so that today the United States is consuming about 20% more eggs per person per year than were consumed before World War II.

Commercial hatcheries now make it possible for producers to secure any desired number of chicks of either sex at any time during the year and for either egg production or meat production. Commercial chick production was three times as great in 1950 as it was in 1930. The only section in the country producing a surplus of eggs is the West-North Central States. Surpluses of turkeys are produced in the West-North Central States, and Pacific and mountain areas. The densely populated region of the Middle Atlantic States is a deficit production area for all poultry products. Poultry compares favorably with livestock in efficiency of production.

The grain mill products industry includes firms producing three related classes of products: breakfast foods, flour and mixes, and animal feeds. Between 1947 and 1964, the assets of this industry increased from $1.3 to $3.7 billion.

FEED MANUFACTURING EXPANSION

The largest and most rapidly growing firm in the industry, Ralston Purina Company, increased its assets from $63 million in 1948 to $364 mil-

lion in 1964. Until 1963, General Mills had been the largest firm in the industry. In 1964, Pillsbury ranked as third largest with assets of $199 million. The bulk of its activities was in flour and flour mix production. Quaker Oats has recently experienced rapid growth—total assets increased from $88 million in 1948 to $188 million in 1964.

American farmers have always produced more than enough food for their fellow man. The average U.S. farmer now produces enough food for himself and 25 others. With population continuing to expand at a phenomenal rate, production must be increased at least 25% by 1975 to maintain present levels of consumption. The formula feed industry must formulate, manufacture, and distribute quality feeds to livestock and poultry farmers that will enable them to meet this challenge with quality products at the lowest possible price. This industry ranks among the top 15 U.S. manufacturing industries and is the largest serving the American farmer.

As the feed industry decentralized, smaller plants have been built closer to customers. Ingredients and finished feeds move shorter distances and trucks offer convenience, timeliness, and flexibility. Improved roads and better trucks contributed much to the switch to truck transportation.

Dealer distribution was the accepted way to do business in the early 1900's. Major feed companies owned or controlled retail feed outlets; except in New England and far Western states, the trend in recent years has been away from company-controlled retail feed stores. During the past 30 yr, many dealers handled several brands. This method of merchandising feed is now disappearing. Major feed companies offer a complete line of feeds that enables dealers to meet all needs of customers. The trend resulting from decentralization of feed manufacturing has been the movement of more feed direct from the plant to the feeder.

Feed manufacturers with national distribution benefit from geographic ingredient diversification because supplies tend to balance and cancel out in the course of a year. Concentrates, in general, contain soybean meal, animal and fishery by-products, fat, minerals, and traces of antibiotics and other substances for disease and parasite prevention and growth promotion. In grain deficit areas such as New England and the Pacific Coast, a manufacturer typically sells a complete feed which is composed of grains and concentrates. In the last decade, many manufacturers of drugs and by-products have developed combinations of drugs and vitamins known as premixes to which protein and grain must be added. Typical complete feeds contain about ⅔ grain, 25 to 35% concentrate, and 5 to 10% premix ingredients. Of course, the animals ultimately receive the equivalent of a complete feed.

Complete Feeds are in Demand

However, the volume of the feed manufacturer depends on whether animals receive a complete feed or concentrate plus grain. The sale of con-

centrates represents to the manufacturer only about ⅓ of the volume of complete feeds. The remaining ⅔, buying, milling, and mixing of the grain, is performed by the feeder or the local grain dealer. Volume of concentrates has been growing more rapidly than total feed production. The American Feed Manufacturers Association estimates that 32% of the 1960 manufactured feed volume was in concentrate form.

While total tonnage has increased at the rate of only 2.1% annually, complete feed equivalent showed annual growth of 4½%. Milling and mixing of the feed grain components are important to feed manufacturers with fixed investment in milling capacity. However, in terms of margin dollars or value added, the grain portion is less important. It is in the concentrate ingredients that research and product differentiation are most important. The rapid growth of concentrates has had two effects. First, concentrates have rarely retarded the growth of complete feeds. This has been a negative factor to the industry as it sells 40% of its volume rather than 100%. Second, and more important, concentrates have expanded as the total feed market. Most of the growth of the concentrates has been in sales to feeders who previously used little or no manufactured feed rather than as a replacement for complete feeds. Use of concentrates varies by geographic area and is heaviest where the local grains are readily available. In grain deficient areas, it is economical to manufacture complete feeds as the grain must be imported in any case. Similarly, the use of concentrates varies by animal class.

Poultry feeds must be processed some way so as to make them edible and thus they consume great proportions of complete feeds. These two factors of geography and animal class work together with such other factors as labor, costs, nearness to markets, and alternate land uses to determine where each animal class grows most economically.

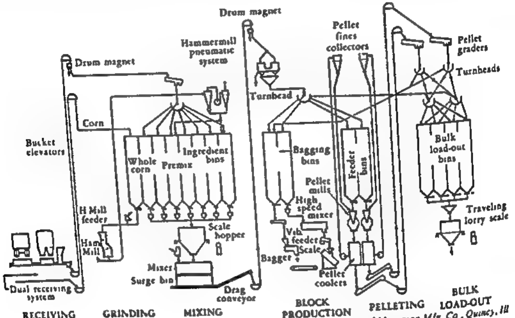
The rates at which feed is converted into end products have changed significantly in recent years. Research by the feed industry, the U.S. Dept. of Agr., and land-grant colleges has focused on conversion of the highest possible percentage of feed into meat. Gains in efficiency of feed utilization will be of smaller magnitude in the future than in the past. Research activity has moved from nutrition and breeding to environment of animals because environmental improvements are most fruitful. Present research is aimed at better operating efficiency and cost reduction for the feeder.

FEED TECHNOLOGY

The feed industry, in some cases, uses terms with definitions far removed from some of those found in Webster's dictionary. Obvious examples include pellets, concentrates, mash, flaking, dressing, or scalping. Feed ingredients are defined adequately in the Official Publication, As-

sociation of American Feed Control Officials, and in the Appendix section of this book.

Feed mill design requires solving hundreds of related individual problems. The end result is a coherent unit that meets all needs. Factors that contribute to satisfaction are: flexibility, profitability, efficiency, quality, low first cost, appearance, location, expandability, storage capacity, and low maintenance. Flexibility means to be able to adjust to highs and lows of sales and remain efficient. Mill designs are not standardized. Probably no industry exercises so little control over raw material, yet is required to produce products within such close tolerances.



Courtesy of Moorman Mfg Co., Quincy, Ill

FIG. 28 2 FLOW DIAGRAM FOR MOORMAN'S FEED PLANT, COLUMBUS, NEBRASKA WHICH CAN MANFACTURE 60,000 TONS PER YEAR OF PREMIX FOR CONCENTRATE TYPE FEEDS

Twelve men operate the mill—one man each for mixing, pelleting, sewing and maintenance; two men for receiving, grinding and block press; three men in the warehouse. It has a head house above the bins containing collectors, turnheads, graders and sifter, spouting and related equipment.

For many years, feed production consisted of the manual blending of ingredients to make a crude ration. Machinery and methods from the milling of flour were incorporated into feed production, namely grinding, sizing, and separating. The production of feed became as complicated as flour milling and so dissimilar that the two were completely separated in production facilities. Roller mills, sifters, screw conveyors, and elevator legs were augmented by batch and continuous mixing lines, hammer mills, pelleting equipment, and all other facilities included in the modern feed plant.

Only in recent years have the tools of scientific management been applied to feed production. Once it is decided what to put into the feed, it is more than just taking a couple of scoops and shovels and putting it in. What about incorporation of microingredients that are put into feeds for a purpose; they are expensive and some return for the amount of money invested is required.

A very concentrated material is put in feed at a level of one part in 400,000 and this is difficult to do. Chemical manufacturers supply a diluted vitamin B_{12}, such as 100 or 200 mg per kilo, a considerable reduction. In the feed plant, another dilution has to be made to 2 to 5 lb per ton, so that very active trace ingredients will be distributed uniformly in the completed feed.

Premixing

Handling these active vitamins or drugs is usually accomplished through premixing. Basic factors of premixing consist of selection of a suitable carrier and oil treatment of the carrier to reduce dustiness. Proper mixing requires the right kind of equipment to provide the proper length of time to give a uniform blend. Good carriers for active ingredients are wheat middlings, finely ground corn, corn gluten meal, corn gluten feed, a good grade of fishmeal or meat scraps, and even minerals such as limestone. Look at the particle size. So-called 20 to 80 mesh means no particles larger than 20, or finer than 80. This keeps the very big and small particles out of the carrier. Next, treat it with soybean oil, corn oil, cottonseed oil, or animal fat. Antioxidants such as BHT (butylated hydroxytoluene), BHA (butylated hydroxyanisole) and santoquin are incorporated. Intimate contact of the inhibitor with the carrier prevents loss by oxidation of the oil-soluble vitamins such as A, D and E.

Vitamin A per se is very sensitive to destruction by oxidation. To prevent this, some companies produce a pellet containing vitamin A. Liquid vitamin A palmitate, insoluble in water, is whipped up in a gelatin solution so there is a very fine subdivision of these particles. It is then sprayed into cold oil. A cross section of a vitamin A pellet under the microscope show thousands of little cells within this pellet, each contains a droplet of vitamin A palmitate. The vitamin A is coated both inside and outside, and has good stability. The gelatin breaks down rather easily in the digestive tract liberating the droplets of vitamin A palmitate where they can be more readily absorbed.

Horizontal Ribbon Blender

An efficient piece of equipment in which to make a premix is a horizontal ribbon blender. The material is not only going around but also goes back

and forth lengthwise in the blender, a rolling action plus the back and forth motion. Ribbon tolerance should be as close as possible without actual rubbing to avoid dead spaces. The central axle should be covered but not so full that you cannot see the tops of the ribbons. First, the mixer is charged, the oil treatment is given and well distributed before any of the active ingredients are put in. The formation of "oil balls" from fines from the carrier must be avoided.

If it is desired to find out how good a blend is, an analysis is made in the laboratory. Not all active ingredients blend to the same degree of uniformity or at the same rate. Some materials, such as riboflavin and coccidiostats, are electrostatic and blend very rapidly. A good blend with riboflavin may be made in 4 min, but it may take 6 min with calcium pantothenate.

The Food and Drug Administration allows on most of the drugs going into feeds ±20% of target and it should be relatively easy to accomplish this with modern feed equipment. Large feed manufacturers covering some 57 plants all over the country had an average of ±7% of a fairly sensitive drug in one period.

Pelleting

Pelleting a feed puts extra pounds of weight on an animal per unit weight of feed consumed. Particularly in broiler chickens, it is quite important. At the present time, more than 95% of all broiler feeds are pelleted. For chickens one day old, whole pellets are run through a crumbilizer. There is less wastage when the chicken grabs a piece of feed and consumes all of it. Part of it is not shaken off the beak or falls on the floor or is washed into the drinking fountain. This tends to give a higher efficiency for the feed. Also, when a feed is pelleted, it stays that way and does not segregate.

Operational Requirements

Good manufacturing practices include: buildings that provide adequate space and protection from the weather for all materials and designed to avoid contamination between different products or ingredients; they should provide adequate lighting, washing, ventilation, cleaning, and toilet and locker facilities. Equipment should be of suitable design and size so that it may be cleaned and maintained in orderly fashion. Measuring, weighing, and mixing should have an accuracy consistent with the nature of the products.

Personnel should be of appropriate experience and education to be certain that feed products have the safety and quality claimed. Ingredients should be identified as to origin, receipt, and disposition. Master formula records should be maintained for all feeds.

A complete batch formula, packaging methods, manufacturing instructions and any precautions needed to prepare the product should be on records retained for 2 yr. Records include information on all critical steps, mixing, processing, inspection, packaging, and warehousing. Equipment is maintained in a manner to prevent products being contaminated with previous feeds. Control measures include sampling, mixing time, and others needed to maintain uniformity of products. Yields of each run of product are checked against theoretical yields and any significant variations immediately investigated. Packaging and labeling are controlled so products are not intermixed. Protection against deterioration after manufacture should be provided.

Laboratory Tests

Laboratory controls include the establishment of tests to be certain that products conform to specifications. Association of Official Agricultural Chemists (AOAC) analytical methods are used wherever possible. Bulk feed tags show the name and address of the first purchaser and the date, product name, and quantity shipped. These practices are of value, not only from an economic standpoint but from the view of improved relationships with customers.

There should be detailed specifications on every ingredient which should be sampled and analyzed from time to time. Bags of feed are kept closed and used on a first in, first out basis. Be aware of possible equipment residues, dust control, and human errors. Whether feed manufacturers purchase complete premixes or manufacture these from individual ingredients depends on individual considerations.

In the mechanics of mixing, partition devices promote mixing and breaking up lumps. Grounding the equipment is necessary to prevent static charges building up on certain ingredients. Mixers should give efficient blending, complete discharge, and dust tightness. Do not overblend.

Mixing Requirements

A perfect feed mixture is one in which the particles are uniformly distributed throughout. The feed mixer must cause the particles to be randomly distributed. The most important particle characteristic is size but shape, electrostatic charge, friction, and resilience are also involved. From a practical standpoint, particle sizes should be similar. The recommendations of the manufacturer of the mixer as to operating speed and capacity, should be followed. Mixing time requirements should be determined by analysis. Efficiency can be greatly improved by proper loading of the mixer. Ingredients having the greatest volume should be added first. Then add liquid material such as fat, fish solubles, molasses, soybean oil or water. For mixing critical drugs and additives, the stage blending process should

be used. This means a batch containing all small items is mixed prior to the final mix. All ingredients used in small quantities thus receive the benefits of premixing.

Vertical Mixers.—The vertical mixer is the most common mixer used by the feed industry because conscientious employees can produce more complicated formulas. The horizontal mixer requires facilities to charge or discharge and horsepower requirement per ton is higher. It is not advisable to add liquids to this mixer; liquids should be added in other equipment and then transferred by a controlled feeder, and introduced by ports or manifolds. Dry feed and liquid are moved the full length of cylinder and thorough, agglomerate-free dispersion is achieved. Liquid addition is controlled by meters coordinated with dry product flow.

Rotary Mixers.—Rotary mixers are between the vertical mixer and horizontal mixer with respect to horsepower per ton. The design of the baffles and shearing plates determine the quality of the mix. It requires more cycle time than other mixers. Liquids should not be added; extremely dense and critical formulations work ideally in these mixers.

Raw materials as well as finished products are mechanically handled. Four types of mechanical handling systems are: (1) bags of material are unitized on conventional wooden pallets; (2) material is palletized but the load can be moved from the pallet without hand handling; (3) the pull-pack method eliminates pallets altogether and utilizes a corrugated or fibrous sheet; and (4) slip sheet transfer method. By unitizing products and handling with mechanical equipment, improved service is rendered to customers. Air is also utilized to move material.

Systems available for delivery of formula feeds to feeders are mechanical delivery, drag chain paddle trucks and screw conveyors, and air pneumatic units. A conveyor panel truck, transporting 1,500 to 2,000 lb per min requires 25 to 45 min at the farm to unload.

Pellet Mills

Variables that affect production of pellets are the physical state of the product, the amount of applied pressure given the feed, and lubrication of the feed. A minimum amount of force and increase in feed temperature are used to extrude the feed through the die holes. The most desirable temperature is 160° to 180°F. A large percentage of animal feeds are pelleted through a 5/32-in. die with an effective thickness of 2 in. requiring between 6,000 and 8,000 psi to extrude feed through the dies. An increase in pressure increases pellet hardness. When a pellet mill is shut down, die holes are cleaned out with a relatively inert ingredient. A pellet mill should never be run without feed.

Packaging involves holding tanks, scales, sacking spouts, bag clamps,

bags, bag shaker, bag closer, tagging and identification, and coding. Fifty-pound multiwall bags are used. Bag shakers and settlers are effective on multiwall bags. Tape closures are neat and attractive. Bags are tagged and coded for quality control. Required on the label are net weight, brand name, minimum protein and fat, maximum fiber content, list of ingredients, and name and address of manufacturer. Automatic packaging consists of high speed scales, magazine type feeders, and automatic closing units.

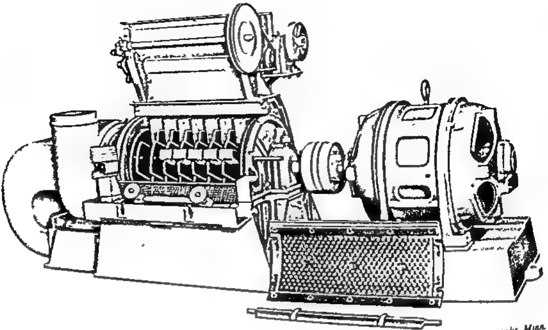
Feed Elevating and Conveying Equipment

Feed elevating or conveying equipment such as the portable auger, vertical auger, and cup elevator are used. Steel bins, round top or flat, storage and small bulk feed bins with hopper bottoms are commonly used. Some examples of farm feed equipment are hammer mills, roller mills, metering or weighing boxes, timer equipment, and scales for trucks and feed wagons. Mechanization of farm feeding improves working conditions and contributes to a higher standard of living for the producer. A few basic kinds of equipment do nearly all the bulk movement jobs.

Feed Preparation Operations

Particle Size.—Square hole, wire-mesh sieves are a common method of measuring particle size. If very small particles are being measured, use a microscope equipped with cross-hairs and graduated mechanical stage. Very fine particles can be measured by sedimentation techniques. Particles are suspended in liquid or air and allowed to settle. These techniques work best if the particles are essentially spherical or cubical. Express results of a particle size analysis by stating the size screen through which all material passes. For example, a specification for grinding might call for all materials to pass an eight to the inch mesh sieve.

Size Reduction.—Crushing is accomplished by applying a compressive force to particles of feed. The roller mill is most frequently used and produces a product relatively uniform in size containing only a small amount of finely pulverized material. If a product is plastic, as steamed grain, the crushed product has the appearance of a flake. Such steamed and rolled material is called "flaked" or "crimped," depending upon whether smooth or corrugated rolls are used. The double roller mill used for this purpose consists of two rolls rotating in opposite directions at the same speed. Rolls are serrated. If the rolls have a speed differential, cutting and shearing will take place. If the rolls are operated at the same speed, the reduction is mostly by crushing. Ball mills, percussion mills, and jaw crushers are mills that also use the crushing principle. Shearing is a combination of cutting and crushing; the action is similar. A rotary-type knife and stationary bar cutter use the shear principle.



Courtesy of Jacobson Machine Works, Minneapolis, Minn.

FIG. 28 3 HAMMER MILL CUTAWAY TO SHOW HAMMERS

Steaming may be used with rolling. Live steam is applied in a conditioner. A more uniform product with less fines can be produced in a roller mill with steam conditioning. The product is preferred by many farmers but steamed grains are no more palatable nor nutritious to poultry.

Mixing and Pelleting Requirements.—Ingredients should be ground as uniformly as possible. Crimped or rolled grains will not mix well with a

Courtesy of Wenger Mixer Mfg Co., Sabetha, Kans.

FIG. 28 4. EXTRUDED PRODUCTS SIZED AND SHAPED AT THE DIE OF A CONTINUOUS EXTRUDER-COOKER

finely ground material. The most desirable material for pelleting passes at least a 7-mesh screen.

Feed Mixing.—Feed mixing disperses ingredients so that each small unit of the whole has the same proportion of each ingredient as the original formula. Many combinations of ingredients with differences in physical properties are blended. Differences include particle size, shape, density, coefficient of friction, resilience, electrostatic charge, and viscosity.

"Mixed" means blended, which implies uniformity. The objective of mixing is to scatter dissimilar parts until they are blended. During the operation there is a possibility for particles which have been mixed to become separated.

Solids have no inherent mobility of their own; however, mixing of solids is often described in terms used chiefly for liquids. The following three possible mechanisms cause mixing: (1) convection—the transfer of groups of particles from one location in the mass to another; (2) diffusion—distribution of particles over a freshly developed surface, and (3) shear—slipping planes of solids within the mass. These actions are accomplished by gravity and mechanical forces. The position of particles within a container is determined by chance, and the effects of chance accumulate until the material is mixed. Particle segregation is due to differences in physical properties of materials and the design of the mixer.

TABLE 28.2

GENERAL GRINDING RECOMMENDATIONS FOR CHICKS AND HENS

Ingredient	Chicks	Hens
Corn	Medium to coarse	Medium to whole
Sorghum grain	Medium to coarse	Medium to whole
Oats	Medium	Medium to whole
Barley	Fine	Fine
Wheat	Medium	Medium to whole
Hay	Fine	Fine

Particle size is more important than other factors in causing segregation. Improvement in mixing made by decreasing particle size can be measured quantitatively by statistical methods. Where very small amounts of solid microingredients are added, the required particle size is very small. Certain ingredients are unstable in finely divided form and may acquire electrostatic charges.

Tests of Mixing.—Small particles of dyed salt are sometimes used as a tracer to measure mixing action. Mixing by V-type mixers permit more rapid distribution radially than longitudinally; materials having a lower angle of repose go to the ends first. Mixing formula feeds in conventional equipment involves so many variables that the exact nature of the distribution of component particles is quite obscure. Mixer performance is evaluated by sampling at the point of discharge. A small quantity of addi-

tive of the same size and approximately the same bulk density as the diluent is easy to mix properly. Additives considerably smaller than the diluent will segregate during the process of mixing and discharge, and appear in high concentration during the first part of the sampling sequence. Partial replacement of the diluent with material intermediate in size between additive and diluent is effective in preventing segregation of small particles of the same bulk density as the diluent. Addition of vegetable oil retards segregation of high density additives due to the fact that particle friction is increased.

The senses are used to evaluate feed quality. Molasses and dehydrated alfalfa meal are detected at 5, 10, and 15% levels by color, odor, and texture of the mixture. The percentage of crimped oats can be approximated at low levels. The quantitative recovery of an addition by counting or sieving is impractical. Chemical analysis is the most reliable method.

Pellets

Pelleted feeds are formed by extruding mixtures of ingredients through die openings. Finely divided, sometimes dusty, unpalatable and difficult-to-handle feedstuffs are formed into larger particles by application of heat,

FIG. 28.5. INSPECTING PELLETED ALFALFA

tive of the same size and approximately the same bulk density as the diluent is easy to mix properly. Additives considerably smaller than the diluent will segregate during the process of mixing and discharge, and appear in high concentration during the first part of the sampling sequence. Partial replacement of the diluent with material intermediate in size between additive and diluent is effective in preventing segregation of small particles of the same bulk density as the diluent. Addition of vegetable oil retards segregation of high density additives due to the fact that particle friction is increased.

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Fig. 28.5. Inspecting Pelleted Alfalfa

moisture, and pressure. Pellets are easier to handle, more palatable and usually result in improved feeding results compared to unpelleted feed.

Pellets have diameters from 10/64 to 48/64 in. and are somewhat longer than the diameter. Where smaller sizes are desired, a 10/64-in. pellet is reduced into the desired particle size by crumbling and grading. Pellet mills use a ring-type die turning about two fixed rollers mounted in a vertical plane. Conventional pellet mills are comprised of feeder, conditioning chamber, pelleting device, speed reduction device, prime mover, and base. Feeders are screw-type with some variation in flight arrangement to accommodate to varying conditions. The feeder provides a constant, controlled, and even flow of feed to the mixing and pelleting operation.

Conditioning is accomplished by the addition of controlled amounts of steam. This supplies moisture for lubrication, liberates natural oils, and results in partial gelatinization of starches. Uniform conditions are extremely important for optimum results. In some cases, small amounts of fat and solubles are added.

Making Pellets.—Knives cut pellets into desired lengths. Pellets are then cooled and dried. Soft-type pellets are produced with equipment using an auger for pressure and die for forming. A blend of mash and molasses is introduced and a rotating auger conveys material to the die and builds up pressure for extrusion. Pressure forces feed through perforations in the die, compressing and forming it into pellets. Pellets are allowed to break off by force of gravity, so sizing is random. Further handling eliminates excessively long particles. The pellets are dusted with bentonite or finely ground cottonseed meal to absorb excess molasses which causes pellets to stick together. Pellets are cooled and dried before bagging or binning. Equipment of this type handles feeds containing 30 to more than 50% molasses. The maximum amount of molasses is governed by the absorptive qualities of dry feed. Recent developments have made possible production of a hard type pellet containing a third molasses.

A unit for pelleting consists of several component parts: supply bin, pellet mill, cooler, crumbler, elevating system, sifting device, and steam supply. The supply bin stores sufficient feed immediately ahead of the pellet mill to provide for continuous operation. These bins are constructed so there will be no bridging or surging. The slope of the hopper sides is never less than 60° and as many vertical sides as possible are used.

Die thickness is a factor in the production of pellets. Some variations in the amount and depth of taper incorporated into entry of the holes in the die are used for special products. All pellet mills incorporate some type of speed reduction device, since die speeds are always less than conventional motor speeds. Two die speeds are used to secure optimum results when a wide range of feeds are produced.

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A means of cooling and drying pellets is essential. Pellets leave the mill at temperatures as high as 100°F and 17% moisture content. Moisture is reduced to 11% and temperature to 15°F above the ambient temperature by passing a stream of air through a bed of pellets. For the production of pellets smaller than 11/64 in. diam, the crumbling process is used. Pellets are ground on corrugated rolls and the resultant product graded by sifting over appropriate screen sizes. Crumbling rolls have 6 to 12 corrugations per inch on the roll surface. Fines are removed while passing through the cooler and handling equipment, and are returned to the pellet mill for reprocessing. Two separations are necessary; one to remove for further crumbling the particles that are larger than desired, and one to remove the particles smaller than desired. These are returned to the pellet mill. Pellets are elevated by bucket elevators or air. Pneumatic conveyors are used for hot pellets. Air systems are corrosion-resistant. A common fan, air duct, and collector can be used for both product cooling and conveying.

Entrained water causes more trouble than any other single factor in pellet mill operation. The addition of liquid fat at low percentages to mash feeds prior to pelleting is accomplished successfully. A most satisfactory method of adding fat is to apply it to the finished pellets. Fat is held at 120°F and necessary pumps, strainer, and piping deliver it to a reheat tank where the temperature can be rapidly raised to 180°F. Some type of metering pump is required to control fat addition.

Automatic Weighing and Bagging

Raw materials are bought and feed is produced, taxed, and hauled on a weight basis. Weighing equipment is available which will accurately batch speedily and accurately weigh, either into bags, trucks or cars. Material flow is the keystone of automatic batching systems. Ingredients must flow evenly from storage to the automatic batching scale. Batching systems are built around weight sensors. If there are many formulas, the punchcard method is available. The card controls selection and weight and other functions. A card reader, an integral part of the control panel, senses the holes in the card (80 vertical columns and 12 horizontal rows) for a total of 960 bits of information. Once the card is inserted in the reader, the information contained on it is channeled to a digital indicator. This keeps the operator advised on what is happening.

Because of weight and measure regulations and to assure themselves of customer good will, feed mills set scale weights so that no bag goes out underweight. Lifting is eliminated to increase production of the bagging personnel. A mechanical settler makes it possible to increase output. Automatic sewing eliminates some manpower. Finished bag weights are checked from time to time.

Eighteen 50-lb bags a minute can be sacked by 1 man. A bag hanger

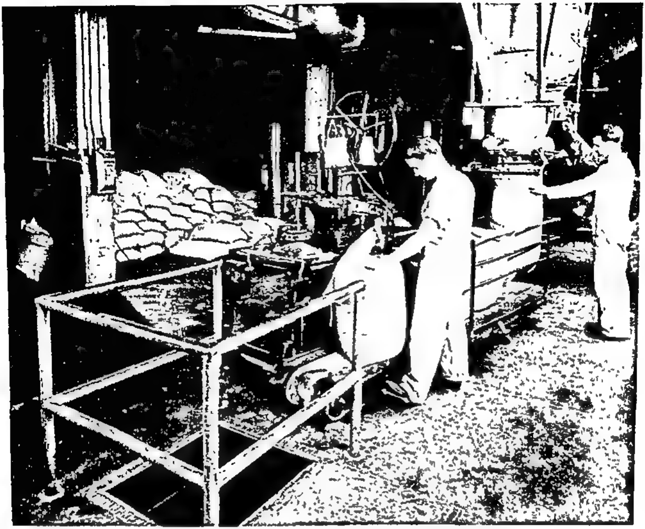

FIG. 28.6. FEEDS ARE TRANSPORTED IN BULK OR IN BAGS TO THE POULTRY FEEDERS; HERE THE FEED IS AUTOMATICALLY WEIGHED AND BAGS SEWN

comes out, picks up a sack and slides it underneath the opening. By electrical impulse the feed drops into the bag. A machine picks up a feed tag and sews it on the bag. All the man has to do is to make sure that the machine is in adjustment. The product is dated as it goes out.

A typical feed plant has a capacity of about 25,000 tons in conjunction with a 2½ million bushel grain elevator and produces 25,000 to 30,000 tons of feed a year. It is better to establish smaller, localized feed mills than a large installation. Most feed plants have a receiving elevator of 15 to 20 tons. Grain trucks carry from 20 to 34 tons of grain. Most feed grains come in by truck.

Approximately 60 ingredients are used in a small mill. Soybean meal, cottonseed meal, and alfalfa ingredients are used in large amounts and it is necessary to have storage space for 1½ cars. Formerly a plant would have five days to unload a car. Now, it has 24 hr in which to get the car unloaded and another 24 hr for which no charge is made. After 72 hr, a charge of $17.50 per day is made for just standing on a siding. At 10 days, it is $38.00 per day. Consequently if severe weather conditions pre-

vail this may be very expensive. The purpose of demurrage is to free cars. Otherwise, companies might use railroad cars for storage, so it is necessary to have some penalty.

Hopper Cars

Hopper cars carry from 50 to 75 tons, even 100 tons. Hopper cars take a minimum of labor to unload providing there is no hangup of the product. Soybean meal will sometimes cake due to water added to control dust. When this happens, it has a consistency of concrete. Elevating soybeans to a storage bin from a 50-ton car takes about an hour; it takes 15 min to spot another car.

Elevators that bring in much grain by cars have a clamp that hooks onto the box car. The door is opened and grain spills out. It takes 20 min to hook the hydraulic lift on the side of a car and 20 min to empty the car. Hopper cars can be either purchased or leased. Some broiler operations take 50 tons of broiler feed a week and have 5 hopper cars running back and forth. These cars are loaded and shipped; then brought into the feed plant empty, filled with feed and run right back again. It is a stipulation that these cars have to be running so much time in a month.

Quality Control Records

Quality control records are kept on all feeds. If someone thinks he had a bad lot of feed, the manufacturer must be able to go back and check what was run that particular day. About nine samples are pulled a day. An outside feed laboratory runs assays on protein, fat, fiber, calcium, phosphorus, and salt in poultry feeds. It costs $6.00 to run 1 sample or about $800 a month just for assays. If a mill continually finds that it is getting inferior products from a supplier, it does not take long to inform the industry.

PRODUCT DEVELOPMENT

Ralston Purina has national and world-wide facilities, 60 feed mills in the United States and many scattered around the World. All these plants, as far as feed formulation is concerned, are controlled through the St. Louis office. Some buying of ingredients is done locally. Large feed companies conduct research work with poultry, livestock, and pets, as well as laboratory animals such as rats and mice. In addition they have chemical and bacteriological laboratories. All of these are used for the development of experimental information which influences formulation. The chain of events when a change of formula is contemplated is as follows: a nutritionist with broad research ability in the field starts the ball rolling. His ideas may come from the research farm, from the literature, from the buying

department on availability of ingredients, or from the sales department. He puts this information together and comes up with a product.

Formulas are set up, checking distribution and seeing that the buyers know approximately how much, when and where. Information on the product is sent to the group which handles registration. This group works with State feed registration people and contacts the Federal, U.S. Dept. of Agr., organizations. If a new product develops, information goes to a group that decides a name. The Product Research Manager is responsible for providing technical information to the advertising and sales groups. The Product Control group must know the formula so that the brand can be identified by code. Feed tags are printed and sent to the mill so they are available when there is a call for the product. The Product Control group sends out the operating formulas to the production plants. Information is sent to dealers, salesmen, and customers so that everybody knows how to use the product. Thus, there are many steps needed to get a new feed out to a customer and many people are involved.

Concentrates have increased in volume much faster than complete feeds in recent years. Firms first offered only a grower-layer poultry concentrate; today, poultrymen can buy starter, grower, regular layer, and cage layer concentrates.

In the 1930's, major feed manufacturers were offering 25 to 40 feeds; today 50 to 75 basic feeds for all classes of livestock, poultry, rabbits, fish, birds, mice, and monkeys may be listed. In addition, nearly every feed is available in 1 to 4 different forms, in different packaging or bulk, with one or more disease-controlling drugs, with different concentrations of a growth stimulant, and with various combinations of these additives. This adds up to 200 to 300 different finished products offered by the dealer.

In a typical plant, 10% of the formulas account for 65 to 75% of the plant's total volume. Restricting the number of feeds in order to improve production and marketing efficiencies is a major problem. Formulas have grown more complex. The number of ingredients used today in a poultry feed is 2 to 3 times the average of 9 ingredients used in 1920. More feeds, more ingredients, and more forms have created the "push button" batch mixing plants which have become necessary in recent years.

Total feed production reaches a peak in April and declines to a low in August. This will vary from one region to another, depending on the kind and amount of livestock and poultry raised. In the South, broiler production usually reaches a peak in August–September and a low in December–January. Confinement rearing helps to smooth out peaks and valleys in production, enabling feed plants to operate more efficiently. Mills are designed with capacity to handle the peak seasonal load.

Demand for food will increase substantially in the years ahead. Popula-

tion in the United States is now 200 million; 244 million is expected by 1975. Transportation costs are critical and will determine where the meat and eggs of the future will be produced, processed and marketed.

Computer-controlled feed mills are not an impossibility. The automatic analysis of ingredients would be fed into the computer and synchronized with the flow of material through the mill. The optimum mix based on analysis and price of ingredients will be manufactured and invoiced under the direction of the machine. There is little doubt that the feed industry will serve fewer and larger feeders managed by better educated farmers. Fewer retail feed dealers will be necessary to distribute commercial formula feeds in the future.

There is no one best way of manufacturing and marketing feeds. In grain-producing areas, concentrates to be mixed with the farmer's grain to make a complete ration is successful. In other areas, complete feeds are more generally used. Feed manufacturers will be successful who make quality feeds and perform related services to farmers more economically than they can obtain in any other way.

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Measuring Values of Feedstuffs

INTRODUCTION

The market price of a feedstuff is not a reliable index of its relative feeding value. It reflects supply and demand by people, not poultry. A particular feed may sell considerably higher than its relative feeding value and at such times is a poor buy. On the other hand, under some market conditions and at certain seasons, some feeds sell for a relatively low price in terms of feeding value and are then good buys. By taking advantage of such fluctuating prices, "good buy" feeds can be added to the usual run of poultry feeds, such as corn, oats, barley and the important protein supplements, and lower the cost of the ration without lowering its nutritional value.

FORMULATION TO PRODUCE FEEDS WITH MOST NUTRITIVE VALUE

In formulating feeds, nutritionists try to supply the most nutritive value for the least cost. The cost of feed required to produce a pound of broiler or a dozen eggs is far more important than the cost per ton of feed. One feed can be more expensive than another but produces a unit of final product at less cost. A method has been devised by Combs of Maryland which evaluates "partial nutritive worth" of feed ingredients in terms of their accepted nutritive composition. It ignores unidentified growth factor activity, amino acid quality and certain other qualities, physical properties, keeping quality, laxative effects, and toxicity. The evaluation is based upon the actual prices of yellow corn and soybean meal. These ingredients were selected since corn and soybean meal constitute the major sources of energy and protein in feeds and a major part of the feed dollar is spent for sources of protein and energy.

A number of other critical nutrients including calcium, phosphorus, vitamin A, riboflavin, niacin, pantothenic acid, choline and vitamin B_{12} need be considered from the standpoint of cost in practical formulation. The values for a therm of energy and a pound of protein supplied by these ingredients are calculated and then by applying these values to various feedstuffs, one calculates the energy, protein, vitamin, and mineral contents to obtain the partial nutritional worth of each feed ingredient. By applying this, feed manufacturers arrive at relative feeding worth of various feedstuffs based on the price of corn and soybean meal.

Digestibility and Availability Important

Chemical composition gives the amount of nutrients in a feedstuff but says nothing of digestibility or availability of nutrients. Digestibility trials give the amount of feed digested and available to the animal. Since urine and feces are excreted together in the bird, undigested nitrogen of the feed is mingled with the nitrogen from the body. The value of feedstuffs is obtained by determining the nitrogen in the feed and feces of a young growing bird. It gives the amount of nitrogen retained and values for its efficiency in poultry. If casein is arbitrarily rated at 100, meat scraps would have a relative protein efficiency of 82. Carbon balances are also possible. Nitrogen and carbon intake and outgo in feces and urine as well as CO_2 are determined by respiration apparatus. It is possible to calculate the amount of protein and fats stored in the body.

Comparative Feeding Trials

Other means of evaluating feedstuffs are comparative feeding trials. As an example, corn, wheat, and oats for hens are compared as protein supplements. This is not very accurate because too many variables are involved. Nutrients are fed below minimum amounts in order to obtain comparative values. Rations are complete in every known respect except the nutrient under test. Purified diets or diets of known value are used as much as possible. In tests of this sort, it is important to eliminate all variables except the one under study. Animals should be of the same age, strain, and source and the parent stock should have been managed uniformly. Birds used in the experiments should be distributed evenly according to size, age, sexual maturity, inheritance, previous egg production, condition, and health. The basal or control ration consists of as few ingredients as possible and enough feed is prepared to last for the entire experiment. The supply is kept frozen to prevent bacterial action. The basal plus the variable factor should produce normal growth, production, or reproduction. The feeds should be analyzed chemically.

It is desirable to have birds consume all their feed before the next feeding. They should be fed regularly. Watch out for possible changes in environmental conditions: the length of day, housing, and temperature. Proper records should be kept on a routine schedule. Birds dying during the experiment should be posted to determine the cause of mortality. Birds should be leg-banded or wing-banded and weights taken individually at frequent intervals. Laying hens should be trapnested to get egg production records. Unless sexed chicks are used, growth results should be weighted for sex. In sampling birds for analysis, keep in mind age, size, sex, and experimental variables and balance as much as possible. Use statistical analysis to determine if differences are significant.

and analyzed. Food, feces, and urine are weighed and analyzed. From this, the amount of carbon and nitrogen lost or stored can be measured. Growth studies of birds fed certain feeds show what the feed can do. Tests made with chicks give an indication of results that might be expected from the feed. Different species of animals do not always respond in the same manner when fed the same ration. The chick and the rat do not need vitamin C, while some farm animals need it. There is a difference in the vitamin D products fed chicks and rats. When feeds are tested on chicks the results are of direct value when used with poultry.

Required Numbers of Chicks for Feeding Studies

The number of chicks required per lot to show significant growth differences in two feeds depends on the size of differences shown. A considerable difference in the value of feed may be tested by 20 to 25 chicks per treatment. Where there is very little difference, many more chicks and replicates may be required. Feeding trials for growth studies of chicks are usually from 6 to 8 weeks because most all nutritional problems show up in this length of time. Differences in lots of chicks at 4 weeks remain so at 8 and 16 weeks because chicks are more sensitive to growth factors in feeds early in life than later on. The amount of feed consumed is a factor governing the rate of growth. The older the birds, the greater the proportion of feed that is used for maintenance. The rate of growth is more a function of food intake than time when birds are fed good rations.

In experimental work with animals, many opportunities for making mistakes are present. These can influence the results so that an incorrect interpretation of the results may be made. Random selection of animals, replication or repeating of experiments, and statistical analyses of the data obtained are used in attempts to avoid incorrect interpretations. Before accepting any experimental results as being absolutely true and accurate, one must consider the number of birds used, the experimental design, as well as the reputation of the researchers who did the work.

PRINCIPLES OF EXPERIMENTAL WORK WITH POULTRY

(I) Biological variability is the most troublesome factor and efforts must be used to overcome or cover its effects.

(II) Numbers of birds to use
- (A) Depends on what is being tested
  - (1) Growth rate
  - (2) Live or die, red or blue, etc.
- (B) Depends on how well controlled the environment is. All groups must be treated alike.
  - (1) Management alike in all factors such as water, feed, and handling.

(2) Get different results due to positions. Overcome by allowing for these effects when they are known.
 (a) North versus south side of house, replication
 (b) Bottom deck cooler, may get less light
(3) Get different results due to previous treatments or conditions.
 (a) Conditions of rearing (disease, housing, etc.)
 (b) Genetic makeup (variety, strain, family, etc.)
 (c) Nutrition of parents on different rations passed through the egg.

(III) (A) Where background of birds is unknown or if all are supposedly alike, randomize to overcome bias (especially where day-old chicks of unknown background are used).
 (B) Where differences as to strain, family, or past history are known, randomize by group or blocks so that some groups of all backgrounds receive each of the experimental feeds.

(IV) In experimental setup, each different experimental feed should be different in only one factor. There should be a control ration to compare each ration. For example:
 (A) Diet A—basal ration (control)
 (B) Diet B— " " + methionine (0.05%)
 (C) Diet C— " " + glycine (0.04%)
 (D) Diet D— " " + glycine (0.04%) + methionine (0.05%)

(V) Mixing experimental feeds
 (A) Mix 1 basal or control ration of 1 batch, if possible. Mix to make 100%.
 (B) Making different experimental rations: variables
  (1) Easiest: Addition of very small amounts to the basal ration. Examples are antibiotics, trace minerals, and amino acids.
  (2) The use of quite large percentages of feedstuffs to be substituted for some other ingredient to make 100% of the ration. Examples are different protein sources, different grains, major minerals, etc. Here one must adjust the rations in many cases to keep them isocaloric and isonitrogenous. Cerelose (glucose), solka-floc (cellulose), and other ingredients are sometimes used for these purposes.

(VI) Measurements in growing chick or broiler experiments
 (A) Rate of growth or body weights
 (B) Feed consumption between weigh periods (to determine the feed efficiency or pounds feed per pounds gain)
 (C) Presence of cripples or culls (scoring systems)
 (D) Mortality and disease
 (E) General appearance of the birds

(F) Effects on future growth and production
(1) Age at first egg
(2) Size of eggs when egg production starts
(3) Rate of egg production
(G) If broilers or other meat-type birds, check quality or grade of the carcass.
(1) Fleshing
(2) Finish and pigmentation
(3) Conformation
(4) Pin feathers
(5) Broken bones
(6) Breast blisters
(H) Energy value of feedstuffs
(I) Vitamin assay (growth, liver storage, blood levels, etc.)
(J) Bone ash, toe ash, blood levels of Ca and P

(VII) Measurements in hen experiments
(A) Egg production
(B) Feed consumption for given periods of time
(C) Quality of eggs produced
(1) Egg weight
(2) Breaking score for shell
(3) Shell thickness
(4) Albumen height
(5) Blood and meat spots
(D) Fertility and hatchability of eggs produced
(E) Mortality and health of birds
(F) Condition of droppings and litter
(G) Presence of vices such as cannibalism, feather picking, or egg eating (score)

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Feeding Systems

INTRODUCTION

The fact that there is no standard system of feeding practiced universally by poultrymen indicates that the method of feeding is less important than the composition of the ration and feed intake. Nevertheless, several systems have evolved over the years that are used at the present time. The first mash feed for layers was formulated about 1908 by U.S. investigators who based it on what layers ate when various feedstuffs were fed free-choice (cafeteria style). This mash was fed as a supplement to grain.

All-mash feeding came into being in 1920 because it saved labor and was simple to feed. Its popularity was followed in the 1930's by the free-choice feeding of mash concentrate and grains. This system eliminated 75% of the grinding and mixing of poultry laying rations. A combination of these two systems of feeding came into use in the East for rearing chicks. In this system, an all-mash ration was fed 6 to 8 weeks after hatching, and a ration consisting of a scratch mixture and growing mash were fed to maturity.

In recent years, there has been a strong tendency for greater confinement in rearing birds and laying stock. This has been accompanied by some developments in feeding systems.

COMMON SYSTEMS

Whole Grain Method

This older method consists of feeding grain as such (no ground feeds) supplemented with some sort of animal protein such as liquid or condensed buttermilk. Production of 250 eggs per bird can be obtained. Fifty-five pounds of dry feed and 185 lb of milk per year are consumed for each Leghorn pullet.

Grain and Mash

Mashes are mixtures of ground feeds. Fed with grains, satisfactory results have been obtained.

All-mash

Mixtures of ground grains, mill feeds, protein, and vitamin supplements are combined to satisfy the requirements of the birds. This system is used quite generally today and reduces labor.

Free-choice (Cafeteria)

Birds are given a chance to select their own feed since feed ingredients are made available separately. Some believe that the hen can balance her rations if given the opportunity better than man can. This ability is shown to a surprising extent by some animals. Where pullets are given an opportunity to consume low, medium, and high percentage of protein mashes with grains, the three groups adjusted the protein to a common level by varying the relative amounts of mash and grain consumed.

Hopper Feeding

Mash is fed in hoppers; grains may be hand-fed in the litter, or hopper fed. With hopper feeding of grains, hens eat the feeds readily and it assures them of going to roost with full crops. There are no differences in egg production between hopper feeding and litter feeding of grains.

Wet-mash Feeding

A wet mash is used to increase food consumption. Since wet mash is more palatable than dry mash, favorable results are obtained when food intake has to be increased. If the birds are consuming enough food in the dry form, the addition of the wet mash will not improve results.

High Versus Low Energy

The following characteristics of high-energy feeds may be listed.

Advantages.—(1) Less bulky feed enables birds to consume more; (2) growth rate and egg production are better; and (3) feed conversion is improved.

Disadvantages.—(1) Higher ingredient costs; (2) scarcity of essential ingredients; and (3) fortification requirements are more critical for feather development.

The choice between high-or low-energy rations rests on economical considerations which depend upon the area and the purpose for which the birds are being fed. In general, a properly fortified high-energy ration gives superior results.

Pellets Versus Mash

This is a modification of the all-mash system since it consists of mechanically compressing the mash into hard, dry pellets.

Grain and Mash

Advantages of mash-scratch grain systems are: (1) whole grains can be fed in part, (2) economical, and (3) common method. Disadvantages are:

(1) extra work in feeding scratch grain, and (2) mash may not meet today's standards.

All Mash

Advantages of all-mash feeding are: (1) best for mechanical feeders, (2) best if feeder space is limited, and (3) simple. Disadvantages are: (1) requires grinding and mixing, and (2) more costly.

Summary

The method or system of feeding does not appear to be the important thing. The important factor is whether the birds consume as much feed under one system as another, and whether with that system they are getting the proper balance of nutrients. Hence, it comes down to a matter of balance of the ration combined with palatability so as to get sufficient feed consumption. The method in itself is not the important factor. Wide variations in feeding methods are possible as long as they do not interfere with the building of a ration complete in all essential nutritive factors. Thus, there is no one best way of feeding poultry.

Continuous hopper feeding of mash is most satisfactory, since it eliminates regular feeding schedules, change of caretaker upsets, and possible lack of sufficient feed. It requires more hopper space. Pullets fed in this manner should have been raised by hopper feeding during the growing period.

In one test, there was a significant loss in egg production and net return per bird over feed cost for Leghorns fed on free-choice grain feeding. There was no significant difference demonstrated for Rhode Island Reds. Egg production showed a tendency to decline during periods of hot weather in the pens receiving free-choice grain feeding. Other experiments fail to indicate which method of feeding is best for either Leghorn or Rhode Island Red layers. Free-choice feeding of whole corn, whole oats, and 22% protein mash proved satisfactory for Leghorns and unsatisfactory for Rhode Island Reds in another test.

A good method of feeding under one set of management conditions may prove unsatisfactory under another. High levels of feed intake must be maintained for rapid growth and high rate of egg production. Feed intake must not be limited. Clean water should always be available under any system. Table 30.1 is the system that is used quite generally at the present time.

Chicks are started on a complete mash containing about 20% protein. Commercial mashes are usually tagged as chick starters or chick mash. The first problem poultrymen may meet is "pasting up." This is adherence of the droppings to the "down" around the vent, especially among heavy

breeds. The condition is intensified by crowding, chilling, and overheating, as well as poor feed ingredients. If this should happen, feed cracked grains for a couple of days. Two types of feeding systems are in use for birds from 8 to 20 weeks of age, namely the complete ration, and the mash and grain system. Birds do not need to eat grit every day, but most poultrymen find it convenient to allow free access to it in a separate hopper. Grit may be added to the mash but is needed only if whole grains are fed. Small chick-sized pellets may have some slight advantage in reducing wastage of floor birds but they cost more. Pellet feeding of laying hens does not produce more eggs than feeding mash of the same composition. Excessively fibrous mixtures are consumed in larger amounts in pellet form. There is a general belief that sudden changes from one mash to another will adversely affect growth and egg production, but it is unfounded. Variation in color and texture of ingredients often affect the appearance of the mash but these variations almost never have any effect on quality.

TABLE 30.1

POULTRY FEEDING SYSTEMS

Age of Birds Weeks	Type of Ration	Shell or Limestone	Insoluble Grit
0–8	20% protein chick mash	None	Unnecessary
8–20	Complete ration; 16% protein growing mash	None	Unnecessary
8–20	Mash-grain: 20% protein mash ad libitum plus grain in hoppers or litter, ad libitum or once a day	None	Ad libitum
Laying hens	Complete ration 15% protein laying mash or 20% protein mash mixed 50–50 with whole grain	Ad libitum	Unnecessary Add ½% to ration or ad libitum
Laying hens	Mash-grain Same as for growing pullets	Ad libitum	Ad libitum

HOUSING CHICKENS

Floor Versus Cage

In California, practically all layers are kept in cages, whereas in New York, cages represent only 15%. Cages were popular in New York State in the early 1930's, but disappeared before the end of the decade. The reasons they failed are: (1) cage layer fatigue was a problem (this is quite well controlled now); (2) lack of insulated laying houses and automatic ventilation systems costs were too high; (3) single bird cages have been replaced by 2 or 3 birds to a cage or colony cages; and (4) labor-saving devices were unavailable. More labor is needed with birds in cages than on the floor.

Now, colony cages have 20 birds in a 3 ft by 4 ft wire cage, and it is possible to get good production despite heavy mortality due to cannibalism. For birds in colony cages, crumbles or pellets, unavailable in the 1930's, are preferred to the mash form of feed because there is not enough feeder space. Feed in this form gives birds an opportunity to fill up faster.

These are merely two ways of handling layers. There is more variation between good and poor producers than between methods of handling. Good managers capitalize on the advantages and offset the disadvantages.

Advantages of cage operations are: (1) more eggs per bird capacity; (2) permits positive culling using a simple record system; (3) culls marketed at better weight; (4) mortality held lower; (5) improved egg marketing possible (cage eggs appeal to consumers and encourages direct selling); (6) cannibalism eliminated; (7) broodiness replaced; (8) timid birds unmolested; (9) less brooding equipment; and (10) birds less flighty.

Disadvantages of cages are: (1) higher investment and necessity to keep cages filled to capacity; (2) many slightly soiled eggs; (3) freezing water (tanks heated by electric tape); (4) loose droppings which require absorbent litter (salt may be lowered); (5) water trough with a right slope necessary; (6) cage fatigue; (7) flies (litter under cages requires ventilation and spraying); (8) mites and lice hard to control; and (9) more labor (feeding hoppers or carts, mechanical feeders, cleaners may be necessary, birds dependent on operator).

Floor Types

Advantages of slat floors are: (1) no wet litter (this saves expense of litter); (2) cleaner eggs gathered often and refrigerated; (3) more birds per house, more feeders, waterers, nests (building insulated to save heat); (4) less labor per bird (operator tends more birds with labor saved); and (5) controlled ventilation possible.

Disadvantages of floor birds are: (1) fewer eggs per bird; (2) lower fertility; (3) fewer males per 100 hens; (4) eggs laid on slats may be broken; (5) sore feet; (6) flies (hardware cloth under the slats allows no access of rats); and (7) cleaning is messy.

Effect of Environment. Environment has a marked effect on dietary needs of caged layers. A diet suitable for floor birds may not meet requirements for cage birds which have less opportunity for activity and movement so maintenance requirements are lower. In addition, temperature is maintained more adequately in cage operations. Cage layer rations are lower in energy than floor type rations; the latter may not perform satisfactorily for cage layers and vice versa. Some phosphorus is obtained from litter when birds are housed on the floor, thus floor bird rations require less phosphorus than caged bird rations. It is generally recognized also

that certain vitamins are available from the litter, paticularly vitamin B_{12}. Allowances are made for extra B-vitamins when birds are housed in cages. Thus, the nutrient requirements of caged layers are somewhat different than those of floor-housed birds. This includes requirements for energy, certain minerals, and some vitamins of the B-complex. With regard to grit feeding to caged layers, the results are in favor of the use of grit.

Pellets are superior to mash for caged laying birds. This shows up in improved feed conversion due to the fact that a great deal of mash is lost in the water, whereas pellets are not carried to the waterers to any extent. Debeaked birds will not consume an adequate amount of feed when such feed is given in pellet form. Some producers feel that changes in ingredients should not be made when birds are in high production, but it is more likely that changes in ingredients can be made as long as nutrient levels are kept constant.

Restricted Feeding

There has been evidence in recent years that there is an advantage for "restricted feeding" of pullets, as measured by subsequent egg production. "Restricted feeding" of birds during the growing period means an actual reduction of nutrient intake below minimum requirements of the birds in order to delay sexual maturity. Restricted feeding, compared to full feeding, delays sexual maturity to some extent and improves early egg size; however, the body's size is soon regained. Feed intake is restricted with equal success by reducing intake of a conventional mash or diluting such a feed with fibrous materials of low nutrient content. This latter procedure reduces the nutrient content and caloric density of the ration below the point where birds can consume all the nutrients they desire.

Pullets are restricted by feeding whole oats, diluting the diet with oat hulls, or reducing the quality of the protein supplement. Care is exercised to avoid vitamin deficiencies in any restriction program. Egg production, average egg size, and feed efficiency are not very different but there is a slight improvement in total eggs and eggs are uniformly of a larger size. Much more work is necessary to determine the effect of restricted feeding on the incidence or severity of diseases, as well as on any physiological changes in birds following restriction and on their longevity.

Controlled Feeding

"Controlled feeding" means giving the birds all the nutrients they require for optimum performance, but controlling excessive calorie intake so that they do not have the opportunity to become extremely fat. This is used particularly with broiler-type breeder hens. In controlled feeding, the factor to watch closely is average body weight which should re-

main steady or increase very slowly throughout the year. Birds that lose body weight quickly lose in egg production also. At the time of the weekly correction in feed allowance, birds losing in body weight should be given more feed than indicated by the feeding schedule; the reverse is true of birds gaining too rapidly in body weight.

Skip-a-day Feeding

As an alternative of reducing the feed intake of growing birds or feeding highly fibrous ingredients in restricted feeding, the "skip-a-day" method for feeding birds is sometimes used. Skip-a-day feeding starts at 12 to 16 weeks of age, depending on maturity and season, and is applied 1 day a week. The amount of feed the first day is doubled less 2 lb. No feed is given in the automatic feeder the second day. On feed days it is necessary to keep feeders running until the birds consume all the feed in the troughs. The operation of the feeder is not interrupted since the aggressive birds will be reattracted to the feed each time the feeder is started. On the "off" days 2 lb of oats are spread in the litter. Grit is fed once a week. The birds are "specked" before skip-a-day feeding is initiated. If birds become sick, full feeding is used until they improve and then skip-a-day feeding is resumed.

A 15% protein ration containing 6% fiber is used. Cockerels and pullets are grown in the same house but separate pens until 10 to 12 weeks of age. Peaks in egg production for off-season birds are 10 to 15% higher, and peaks for in-season flocks are 5 to 8% above those on restricted feeding. An advantage of the plan is the complete elimination of range-rearing of birds. With year-round confinement rearing there is more positive control over growth and health of the pullets. Developing hardy replacement stock for the laying house is the most important yearly task on the poultry farm. Restricting the feed intake and lowering the energy level in the ration increases hardiness of stock at a savings of cost. Skip feeding is a practice sometimes used in animal husbandry to keep animals on feed. Feed withheld one day every week keeps the animals on the hungry side and their appetite keen.

Birds perform reasonably well under confinement but, of course, they cannot supplement their rations as if they were on pasture. Some believe that feed restriction is of little or no value when practiced on egg strain birds, but may have some merit on broiler strain replacement stock.

Birds eat to satisfy their energy needs. Restricting feed intake has also been tried on the laying flock by closing hoppers. The feed intake has been controlled to 70% of that consumed by birds having free access to feed. Results favor the limited feeding program. If the mash is medium or high in energy, birds are able to make up for the loss of feed on the skip day by eating more on the following days. On the other hand, if the birds receive low energy rations they are unable to consume enough following the

skipped day when it becomes available again because they were already eating to full capacity. During the skipped day, pullets scratch through the litter to look for feed previously wasted. This offsets to some degree the intended removal of feed from the pen.

Significant differences in the 20-week weights of the birds are directly related to the energy levels in the feeds, irrespective of skip feeding. There is no significant difference to skip feeding in age of onset of egg production or rate of egg production with birds seven months of age. Mortality during the laying period is not attributed to this treatment.

Free-choice Feeding

Advantages of free-choice or cafeteria feeding are: (1) simplifies use of home-grown grains; (2) saves grinding, labor, and mixing expense; (3) most economical—uses home-grown grains; (4) allows variation in individual requirements. Disadvantages are: (1) requires extra care and feeder replacement; and (2) not adaptable to mechanical feeders.

Feeding Semisolid Buttermilk to Poultry

Semisolid buttermilk was formerly used to some extent as a supplement to grains and as a health aid. Baby chicks were fed starting mash in hoppers moistened each morning with semisolid, diluted half and half with water to last the chicks 1 hr. At noon green feed was fed to control "picking" or cannibalism. About 2:00 P.M. 1 lb of semisolid buttermilk was mixed with 5 lb of chick-sized scratch and fed on top of the mash. This procedure was carried out for the first five days and then they were given starting mash. At three weeks of age, they were started on a conditioning ration. Once a week 2 lb of semisolid buttermilk mixed with 1 lb of wheat bran was fed ½ day each week to the exclusion of other feeds. After 8 weeks, 1 lb of semisolid buttermilk was mixed with 5 lb of grain and fed to the birds until they were housed. It was believed that the birds would be in better condition to stand the strain of heavy production longer. Semisolid buttermilk was added to the grains or mash in various ways, namely poured over the mash, made into a crumbly mash, fed separately as milk and grain, soaked grains, soaked oats, all for the purpose of building up body weight and conditioning the birds for egg production.

Phase Feeding

Phase feeding simply means the offering of several different rations to laying hens during various phases of the laying cycle. It is an attempt to provide hens with correct nutrition according to the production and age of the birds. Why is this important? To increase profits. Let's look at some of the practices used, and learn why this type of feeding came into being. For many years the National Research Council listed the protein require-

ments for laying hens at 15%, although research has shown that 13% is adequate for maximum production. Commercial rations run 17% protein, some as low as 15%, and some as high as 21%. If the amino acid composition in the feed was aligned to the needs of the bird, then theoretically we should be able to lower percent protein. Also, with a lower energy feed, the birds eat more feed and tend to lower the percentage of protein needed in a ration. If birds eat 30 lb of feed per 100 hens per day, they will take in more protein if the feed has 15% than if the birds eat only 20 lb per 100 birds per day. There are a lot of other things that can influence feed intake. If the temperature goes above 85°F for any extended period of time, feed consumption goes down considerably. If total feed consumption goes down, the percentage of protein in the feed must go up or production will suffer. After the birds are producing 80% you would expect that their nutrient requirements will be somewhat different than if they are laying at 50% production. These factors thus explain why differences in protein levels in feeds may be advantageous. As many as 12 different feeds have been fed to a flock during a 14-month period; the changes were mostly in protein content. Usually only two factors are used in making adjustments: (1) age of the bird, and (2) percent of egg production.

Laying birds need 17 to 18 gm of protein per day based on 70% production. If birds are eating 17 lb per 100 birds per day, the percentage protein of the ration has to be 23.4% to get this 17 to 18 gm of protein. On the other hand, if birds consume 20 lb per 100 hens per day, this figure drops down to 19.9% protein. Because modern rations are higher in energy than in the past, a flock that is first coming into production may not consume as much feed as if feeds of standard levels of energy were used. In commercial egg production daily intake per 100 hens may vary 15%.

Thus, the percentage of protein in laying feeds is primarily influenced by the energy level. If during the laying cycle production drops, the percent of protein in the ration would also; however, the protein intake is maintained. This is why phase feeding has become popular; if you start out with 17½% and feed it for a specified period of time, the percent protein can drop as the hens get older. For each 1% protein dropped, this would lessen the cost of the ration about $1.00 per ton. Often a saving of about $2.50 per ton is possible.

There are a couple basic reasons why this program does not always work well in the field. Commercial egg laying strains of birds reach sexual maturity and start laying eggs at 20 weeks of age at which time they weigh 3.2 lb. Production goes up rapidly and peaks at about 80%, but comes down as time goes on. A factor that complicates this is that mature body weight of 4 lb is not reached until the birds are 40 to 45 weeks of age. Thus, dur-

ing the peak of production they are also increasing in body weight. When birds are 40 to 45 weeks old, the feed can be changed from 17½ to 15½% protein.

Problems in Phase Feeding.—But there may be problems connected with phase feeding. For example, a feed company knew that the age of a flock of birds was over 40 weeks and they dropped from an 18½% protein to 15½% protein feed. Production dropped to 60%, a 25% drop in a 2-week period, and there was 80 to 85% of small and medium eggs. What had happened was that feed consumption stayed the same and there was a deficiency of protein. Birds were getting inadequate protein because these birds were only eating 21 lb per 100 birds per day.

A new poultryman thought he was in trouble. His birds were down to 40% production at 32 weeks while on a phase feeding program. The mill knew of his case and asked him what his birds were producing and he said 60% and they looked on their chart and it said that he now only needed 15% protein regardless of what the production was at that time. The birds had a bad case of Blue Comb and were eating only 18 lb or less per 100 birds per day. These are some of the problems that arise. But on the other hand, if you are in the feed business and not employing phase feeding, customers are going to ask why, since they have heard about it and want to save money.

Feed dealers may use about 1,400 lb of corn and 600 lb of concentrate to make an 18% laying ration. Companies using phase feeding do this in the early production cycle of a flock. If they decide to change the feed, they may use 1,600 lb of corn and 400 lb of concentrate. This comes out to be about a 15.3% laying ration. This works well because it is convenient to the dealer. The concentrate contains protein sources but also many other nutrients. A drop in protein would also lower critical nutrients provided by the concentrate, therefore this practice is faulty. Let us look at it from another angle. A feed manufacturer feeding 50 flocks of laying hens will be manufacturing four different rations sometime during the 12 months of lay, and someone may deliver the feed to the wrong place. Phase feeding should not be considered unless it is known how much the birds are eating.

Phase feeding is here and it is going to increase. There has to be close cooperation between poultrymen and feed manufacturer. Poultrymen have to cooperate with the feed companies in order to apply the program correctly. Unless it is known what the birds are eating and their age, it is impossible to do it properly. Usually problems come during the summer when temperatures are above 80° to 85°F, and birds eat less. Different temperatures influence the amounts of feed eaten.

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Nutrient Requirements of Poultry

INTRODUCTION

More is known about the nutritional requirements of chickens than that of any other species. The National Research Council's Bulletin "Nutrient Requirements of Poultry" is generally recognized as the best available on quantitative requirements. Requirements are given in terms of the quantity per day or per pound of feed which will prevent the appearance of deficiency diseases. Certain precautions must be noted. In the first place, they are minimum requirements and provide no margin of safety. There will be little or no body storage of the factors involved when fed at these levels and, thus, there is no cushion against temporary deficiencies. Requirements are based on average results and individuals vary considerably from the average. It follows that those birds which have a higher than normal requirement actually receive less than they need. When requirements are expressed per pound of feed, feed consumption must also be given consideration. What the bird needs is a specific daily intake. With a trend toward higher-energy feeds, 2 lb of high-energy feeds may do what 3 lb of a lower-energy feed formerly did. Therefore, we must put into 2 lb of the high-energy feed every critical nutrient that was present in the 3 lb of the older ration. Feed consumption may be reduced during hot weather, yet requirements for some nutrients do not drop with higher temperatures. Obviously, blind addition of critical nutrients to feeds does more harm than good, but it is usually better to err on the side of feeding more nutrients than may be needed than to risk a feed deficiency.

MINIMUM REQUIREMENTS

The minimum requirement is generally recognized as the smallest amount of a nutrient that will support normal performance or prevent detectable signs of nutritional deficiency. The optimum requirement is the amount required for optimum health. The distinction between these two terms is largely a function of how accurately one can detect the minimal need. We are forced to deduce an allowance for safety over and above the minimal estimates. This allowance must cover the variation between minimum and optimum requirement. There is good reason to believe that the nutritional requirements of individuals are different.

Because of the greater economic importance of chickens, their nutritive requirements have been studied more extensively than those of turkeys,

guineas, pigeons, ducks, and geese. Qualitatively, the nutrient requirements of chickens are the same as those of other animals but quantitatively they are appreciably different. An important difference between chickens and other animals is that the feed of chickens consists mostly of concentrates, whereas that of cattle, horses, sheep, and goats includes a rather large portion of roughages. Chickens are usually fed all they can be induced to eat, not rationed to a fixed quantity of feed each day. Full feeding is desirable because rapid growth is generally necessary for the economical production of meat, even though they utilize their feed less efficiently.

EGG PRODUCTION AND FEED SUPPLY

High egg production cannot be maintained if the feed supply is limited. The embryo develops outside of the body and the food of the young is not prepared within the body of the mother. In the chicken, the feed supply of the developing embryo is independent of the contemporary feed supply of the mother. Once the fertile egg is laid, the nutritional state of the contained embryo is fixed.

Diet may affect reproduction in the chicken in several ways. It may affect the quantity and fertilizing capacity of the sperm produced by the male, egg formation by the female, as well as composition of the eggs and hatchability of those that are fertile. Deficiencies of vitamins A and E lead to a failure of sperm production. Although male chickens may eventually become sterile if kept on diets that are markedly deficient in vitamin A or E, they are able to subsist for a relatively long time without losing their ability to fertilize. It is difficult to decrease the sperm production or fertilizing capacity of adult male chickens by dietary means unless a deficient feed is fed for a long time. Further, there is no experimental evidence that sperm production of healthy male chickens can be increased by diets. However, there is an abundance of evidence that egg production in chickens is affected by diets. Early observations indicated that eggs laid during the winter did not hatch as well as those laid during the spring and that fewer eggs hatched if the chickens were confined than if they had access to sunshine and range including green feeds. The explanation is that eggs produced during the winter did not hatch well chiefly because the chickens did not get enough vitamin D because the birds did not have exposure to sunshine. Green feeds improve hatchability because they supply vitamin A and riboflavin.

Protein Supplements and Egg Hatchability

The difference in the effect of plant and animal protein supplements on hatchability is because the latter contains one or more vitamins such as riboflavin not present in the former. If the diet of the newly-hatched

chick is deficient in protein, vitamins, minerals, or energy-producing nutrients, growth is retarded and development abnormal; if severe enough, the chick dies. From the standpoint of nutrition, the most critical period in the life of the chick is the first few weeks after hatching. Hence, in devising diets for growing chicks, special attention should be given to supplying the proper amount of protein of good quality along with fully adequate, but not excessive, quantities of minerals and vitamins.

TABLE 31.1

APPROXIMATE MINIMUM PROTEIN NEEDS OF LAYING HENS RELATED TO FEED CONSUMPTION[1]

Daily Feed per 100 Hens (Lb)	Protein Requirements Phase 1	Phase 2 (% of Diet)	Phase 3
17	22.0	. . .	. . .
18	20.7	. . .	. . .
19	19.6	18.5	17.4
20	18.7	17.6	16.5
21	17.8	16.8	15.8
22	17.0	16.0	15.0
23	16.3	15.3	14.4
24	16.0	14.7	13.8
25	. . .	14.2	13.3
26	. . .	13.5	12.7
27	. . .	13.0	12.2

[1]Assumes balanced amino acid pattern in the proteins
(Total sulfur containing amino acids equal 3.6% of the protein.)

Protein in Egg Production

Nutrition is most critical during the early stages of egg production while body weight is increasing. As the hen reaches maturity, because of the reduced need for body gain and as egg production declines, daily protein needs decrease. Methionine and lysine are the most critical amino acids since most proteins are not liberally supplied with these two amino acids. Suggested daily allowances for protein for the three phases described are as follows:

Phase	Production Stage	Protein Requirement per Hen per Day (Gm)	Protein Requirement per 100 Hens per Day (Lb)
1	To 40 weeks of age	17	3.74
2	40 weeks to 65% production	16	3.52
3	Below 65% production	15	3.30

Assumption is made that protein is well-balanced in amino acid composition and total sulfur containing amino acids equal 3.6% of the protein.

Birds consuming 22 lb of feed per 100 birds daily require 17% protein to

TABLE 31.2

BROILER PRODUCTION CHARTS

Daily Broiler Feed Consumption		Daily Broiler Water Consumption	
Age of Birds (Wk)	Lb of Feed	Age of Birds (Wk)	Gal. of water
	per 100 Birds		per 100 Birds
1	2.9	1	.45
2	4.0	2	1.1
3	6.5	3	1.5
4	9.2	4	2.0
5	11.0	5	2.4
6	14.5	6	2.7
7	16.0	7	3.2
8	18.5	8	4.1
9	21.0	9	4.2
10	23.0	10	4.9
11	25.5	11	5.2
12	29.0	12	5.5

Source: Merck & Co. Serv. Bull.

obtain the recommended daily intake of protein; if 25 lb of feed were consumed only 14.9% protein would be required. In addition to changes of protein intake, calcium concentration may be increased as the year progresses to remedy poor egg shell quality. Energy level in phase 3 is reduced to control excessive deposition of body and liver fat. Records of feed consumption are mandatory to take advantage of phase feeding. Rations are closely tailored to actual flock conditions to insure adequate

TABLE 31.3

BROILER FEED CONVERSION (LB OF MEAT PER 100 LB FEED)

Meat (Lb)	Feed Conversion	Meat (Lb)	Feed Conversion
30	3.33	40.5	2.47
30.5	3.28	41	2.44
31	3.23	41.5	2.41
31.5	3.18	42	2.38
32	3.13	42.5	2.35
32.5	3.08	43	2.33
33	3.03	43.5	2.30
33.5	2.99	44	2.27
34	2.94	44.5	2.25
34.5	2.90	45	2.22
35	2.86	45.5	2.20
35.5	2.82	46	2.17
36	2.78	46.5	2.15
36.5	2.74	47	2.13
37	2.70	47.5	2.11
37.5	2.67	48	2.08
38	2.63	48.5	2.06
38.5	2.60	49	2.04
39	2.56	49.5	2.02
39.5	2.53	50	2.00
40	2.50	...	...

Source: Merck & Co Serv Bull.

TABLE 31.4

FEED AND GROWTH DATA FOR LIGHT BREEDERS

Period Days	Avg Feed per Bird for Period	Cumulative Feed per Bird to Date	Avg Weight per Bird at End of Period	Gain per Period	Feed per Lb Gain	% Feed Used by End of Each Period	
						to 150 Days	to 50% Prod.
1–28	1.27	1.27	0.57	0.48	2.22	6.39	5.32
28–56	2.88	4.15	1.46	0.89	2.84	20.90	17.39
56–84	4.63	8.78	2.30	0.84	3.81	44.23	36.79
84–112	4.36	13.14	2.83	0.53	4.64	66.19	55.07
112–140	4.74	17.88	3.36	0.43	5.48	90.07	74.93
140–150	1.97	19.85	3.44	0.18	5.77	100.00	83.19
150–173	4.01	23.86	...	...	...	...	100.00
Avg 174[1]	4.84	23.94	...	...	...	...	100.00

[1]This is average age when 50% production was reached.

TABLE 31.5

FEED AND GROWTH DATA FOR HEAVY BREEDERS

Period Days	Avg Feed per Bird for Period	Cumulative Feed per Bird to Days	Avg Weight per Bird at End of Period	Gain per Period	Feed per Lb Gain	% Feed Used by End of Each Period	
						to 150 Days	to 50% Prod.
1–28	1.24	1.24	0.65	0.56	1.90	5.48	4.48
28–56	3.46	4.70	1.85	1.20	2.54	20.80	17.01
56–84	5.04	9.74	2.85	1.00	3.41	43.11	35.25
84–112	5.20	14.94	3.73	0.88	4.00	66.13	54.07
112–140	5.97	20.91	4.41	0.68	4.74	92.56	75.67
140–150	1.68	22.59	4.68	0.27	4.82	100.00	81.75
150–178	5.04	27.63	...	...	...	...	100.00
Avg 179[1]	6.29	28.39	...	...	...	...	100.00

[1]Average age when 50% production was reached

nutrition and prevent overfeeding of expensive nutrients. Tailoring feeding programs to bulk need is probably the most significant development in phase feeding rather than the phases themselves.

A 45% increase in protein supply over that available in 1960 will be needed by 1975. Research on protein for human consumption is concerned with the development of foods which are well-balanced, attractive, and economical in proteins. Peanuts and cottonseed have not been exploited as much as soybeans. Feed and growth data for light and heavy breeders are given in Tables 31.4 and 31.5.

TABLE 31.6

DAILY FEED AND WATER CONSUMPTION FOR TURKEYS
(LB PER 100 BIRDS)

Age (Wk)	Broad-breasted Bronze	Beltsville Small White
1	1.8	2.0
[illegible]	4.4	5.0
3	8.6	8.5
4	11.4	10.0
5	14.3	12.5
6	17.5	12.8
7	20.5	18.5
8	25.6	19.0
9	29.0	24.0
10	32.7	25.7
11	34.0	28.5
12	35.5	28.5
13	39.0	31.4
14	41.5	37.0
15	45.0	37.0
16	47.5	40.0
17	49.0	44.0
18	55.5	48.0
19	60.0	50.0
20	61.0	55.0
21	61.6	60.0
22	63.0	62.0
23	67.0	65.0
24	67.8	67.0
25	68.0	—
26	77.0	—
27	80.0	—
28	82.0	—

Water consumption

Age (Wk)	Gal. Water Consumed
1–3	1.1–2.5
4–7	3.7–8.4
9–13	8.8–14.2
15–19	16.7
21–26	13.5–17[1]

[1]Varies according to weather
Source: Merck & Co Serv Bull

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Sanitation

IMPORTANCE OF CLEANLINESS

Good housekeeping in the feed and poultry industries is a tough job and takes time. The threat of Federal inspection has been an influence for better housekeeping. State legislatures are establishing regulations with respect to all sources of pollution. People move out of the cities into areas where agriculture enterprises have long flourished and are interested in fresh air, no odors, etc. Poultrymen and feedmen will be unhappy unless they keep clean and sanitary operations which can pay off in better health and production of poultry.

SUCCESSFUL SANITATION PROGRAMS

A successful sanitation program is based on common sense. Cleaning of houses consists of the following: removal of brooders, feeders, waterers, roosts, and other equipment. Litter is removed and the floor swept clean. The house is washed down inside and out to eliminate dust and cobwebs that provide hiding places for organisms and reduce the biological load of the disinfectant. A disinfectant is applied with a power sprayer over every inch of the ceiling and walls inside and out. A band of soil 6 feet wide around the outside of the house is sprayed with fuel oil. If leukosis has been a problem on the farm, another spray of disinfectant is applied before fresh litter is introduced. Litter is dusted with a suitable insecticide. Finally, each house is kept empty for two weeks.

On the farm, isolation and sanitation are the best weapons of defense if they are properly planned and executed. Concrete floors should be used because it is impossible to get good disease control in houses with earth floors. It reduces the amount of litter needed and less work is incurred in cleaning between broods. Brooding quarters must be restricted to certain personnel who are not permitted to visit other parts of the farm. No visitors should be allowed at any time. Screen houses to keep out wild birds. Provide a pan of disinfectant and a stiff brush to clean boots, a change of clothes when possible, and a lock on the door to keep everyone out of the house but caretaker and owner.

Baby chicks should be delivered in sanitary chick boxes (not used boxes). On one farm a flock was so badly infected that loss from leukosis averaged over 20% by 20 weeks of age, yet when the same birds were placed on another farm under isolation the breeder seldom ever had any losses

from leukosis. Sanitation starts with the hatchery. No one except the hatchery crew ever goes into the incubation rooms. There is no mixing of the birds from flocks A and B anywhere along the line. Crews for sexing, debeaking, and decombing come to the hatchery clothed in freshly laundered uniforms. All tools used on the farm are sterilized. Workmen on the farm are forbidden to own chickens at home.

Sanitation is cleanliness. It is not necessarily expensive, yet lack of it may prove very costly. Where installations are of sufficient size, the use of steam cleaners prove efficient and economical. The use of a chlorinated general cleaner for some general applications may be feasible. The presence of residual chlorine in the wash water tends to hold down bacterial growth. The domestic fowl assumes some importance as a carrier of disease. The virus of several strains of encephalomyelitis which infect horses and man find a natural reservoir in the hen. Many types of *Salmonella* are found in poultry as well as eggs. *Salmonella typhimurium*, the most common causing infection, is found more frequently in hens than in all other animals combined. Ornithosis (psittacosis) in domestic fowl assumes an increasing role in the epidemiology of the disease. The fowl mite causes an itchy dermatitis on the hands of the poultry attendants. Thus, public health officials have an increasing interest in sanitation of the poultry farm. Even a casual inspection of the available reports of mortality in commercial and farm flocks is sufficient to convince anyone that the loss of fowl by death often assumes serious proportions. With the concentration of the poultry population in particular areas, poultry mortality is sure to increase unless preventive measures are applied. Flock owners should be provided with essential instructions in the fields of bacteriology, immunology, parasitology, pathology, embryology, genetics, nutrition, and poultry management. Spearheading it all is the necessity for an understanding of how bacteria live, multiply, and travel from place to place, as well as what they are capable of accomplishing. It is obvious that carrying out the sanitation requirements is essential to the well-being of the poultry flock, and rests entirely in the hands of the owner and those he employs.

Poor Sanitation May Cause Diseases

An example of the necessity for the application of sanitation is pullorum disease, starting with the hen which lays infected eggs from which are hatched infected chicks, resulting in an infected incubator, and infected shipping boxes. Infected chicks infect other chicks in the brooder house which carry the infection to the feeding grounds and ranges. The infected young stock then become infected adults and the cycle is repeated. In the case of *Salmonella* infection, infected birds cause fecal contami-

nation of feed, water troughs, yards, and eggs. *Pasteurella multicoida* causes fowl cholera which may persist for several months since organisms remain in soil and manure. Close contact by birds facilitates spread of infection. The organism causing fowl cholera has been isolated from mites taken from sick birds, as well as from house flies. Many other specific infections including avian tuberculosis and pneumonia, *Spiracheta gallinarium*, pneumonia and *Staphylococcus aureus* demand control measures through cleaning and disinfection of houses and equipment for proper carcass disposal. Involved in these infections are soil, ranges, mites, flies, ticks, houses, brooders, incubators, chicks, eggs, fowl, and humans. In each instance, sanitation plays an extremely important part in the disease control program. Regular washing and sanitizing of housing equipment and utensils, immediate disposal of dead birds, eradication of rodents and insects, and clean incubators and personnel are important. Proper cleaning compounds and an adequate scrubbing with suitable brushes are of great importance. Flies, roaches, and ticks should be eradicated and rodent control measures properly applied. A concrete cleaning platform, open or enclosed and properly drained, makes it easy to clean and sanitize portable equipment in one central location. Isolation of ill birds and immediate removal of dead fowl are important. Above all, the proper attitude toward sanitation on the part of the owners and employees is important to the health of the chickens.

SANITATION IN THE FEED INDUSTRY

In the case of the feed industry, good housekeeping has been preached for many years. Keeping their premises clean and free from insects takes eternal vigilance. The only insurance against contamination is to prevent the propagation of weevils and beetles or any sort of creature capable of contaminating feeds. If bugs live long enough to find a place of abode, contamination begins at once. There are accumulations of dusty materials in spouts, trunks, and housings of machines. The primary cause for much of this is vapor condensed on the inner surface through which feed passes.

There are many methods by which adult insects can be prevented from instituting contamination. Sprays that are nonflammable and harmless to human beings are employed daily in guns and atomizers that are not expensive to kill insects upon contact. Fumigants can be used with gratifying results within machines and equipment. Pulverized diatomaceous earth is used in the Southwestern U.S. to prevent insect damage to grain. It is nontoxic and is used at levels of 7.5 lb per ton.

The Need for Inspection

Inaugurating a program of sanitation consists of outlining the work to be done in simple, logical steps as follows: general cleanup and house clean-

ing measures, insect control, rodent control and routine inspections which will reveal progress made in each of the above categories and serve as periodic condition reports. The inspections must be thorough and complete including both inside and outside and detailed enough to include suggested improvements in operations to be made. Check the surroundings outside the plant for piles of accumulated trash, or spilled or souring grain. Have weeds been allowed to grow around the tanks and along the tracks, providing cover for rodents? Is a suitable place provided for burning trash? Rodents will not harbor under equipment that is on racks 18 in. above the ground. They do not feel secure enough to establish a quarter. Check windows to be certain that they are properly screened to prevent rodent entry. Screening should be ¼-in. hardware cloth in order to keep out both rats and mice. Eliminate standing pools of water due to poor drainage.

Exterminating Rodents

Professional exterminators are frequently employed to clean up rodents in an area. After the cleanup has been accomplished be certain that the premises are completely cleared of trash and places of harborage. Warfarin baits can be expected to do a good job and keep down rodents. It is not a quick killer and baits must be available in sufficient quantities so the rodents may feed from 5 to 14 days.

Rodent control can be summed up briefly. Build them out, starve them out, and check thoroughly places where they can enter such as open and unscreened windows, and cracks in foundation walls. Any hole large enough to get your thumb into will allow a rat to get in. Where electrical wires or pipes pass through walls are common places of entry. Rodent proof such places with metal shields. In the country elevator, examine carefully along the edges of walls and particularly around the dump for signs of rodent activity. Look for tracks in the dust and presence of pellets. In larger elevators where a conveyor belt is used to transfer the grain from the tank, examine under the entire length of the belt for signs of rodent and insect activity. Pay particular attention where junk, used machinery, and old sacks have been allowed to accumulate. Get rid of all such material. Pigeons and sparrows habitually fly in and out of the tops of elevators and in the event that there are open top bins, the chance of bird excrement contaminating the grain is very great.

PREPARATION OF COUNTRY ELEVATOR

In preparing the country elevator for receiving new wheat and other grains at harvest time, it is necessary to clean and spray the elevator bins in order to prevent infestation from beginning as soon as the grain has been placed in the bin. The entire wall surface should be brushed down to re-

move as much dust and loose grain as possible and the bottom should be scraped clean. The bins should then be sprayed under high pressure to force the insecticide into crevices and holes. New grains which come in in an infested condition have picked up that infestation after it left the field. If grain taken in in July is to be housed for 30 days or longer in any type of storage, it should be fumigated. Fumigants are of three basic types: (1) carbon tetrachloride, ethylene dichloride, and ethylene dibromide combinations; (2) carbon tetrachloride, carbon bisulfide, and ethylene dibromide combinations; and (3) carbon tetrachloride and carbon bisulfide combinations. Manufacturers supply dosages for different types of bins. Factors influencing dosages are temperature, type of grain, the amount of dirt and moisture in grain, and most important of all, the type of bin. Spraying the cars in which the grain is loaded is another means of holding down insect infestation. They should be sprayed the night before loading. At no time should materials be sprayed directly on the grain.

THE SALMONELLA PROBLEM

Public health agencies have alerted the poultry and feed industries to the Salmonella problem which causes food poisoning in humans. Over 650 different *Salmonella* species are known. The extent to which feed ingredients are contaminated is uncertain. In general, *Salmonella* comes from fecal contamination from rodents, wild birds, and probably insects. Most pathogens are easily destroyed by chemicals and heat. The usual heat processing effectively destroys *Salmonellae* in meat and poultry by-products used as feed ingredients. Thus, ordinary precautions should prevent *Salmonella* from being a problem. Eggs are suspect because poultry are susceptible to many diseases caused by *Salmonella*. *Salmonella typhimurium* causes paratyphoid infection in chickens and turkeys. *Salmonella* organisms are killed by heating up to 180°F (or 165°F for 20 min). Contaminated processed materials when mixed in feed produce disease in livestock and poultry and disease can then be spread from them to man. To prevent this allow only authorized persons in the plant.

Sanitary Precautions

Assign labeled coveralls and tools to specific areas in a plant and clean equipment to prevent buildup of pockets of Salmonella contamination. Prevent moisture from circulating through the plant. Separate raw materials and processed material areas by a solid, nonleaking wall or floor. Prevent air and dust circulation between raw material and processed material areas. Live animals and birds should not be permitted in processed material areas. There should be adequate showering, dressing, and disinfecting facilities for employee use. Equipment used in the processed

material area should be marked and used only in the area designated. Personnel assigned to raw material areas should not be used in the processed material area, and vice versa. Processed products should be kept dry at all times. Bacteria require moisture to multiply and thus finished products, or containers or areas where these are stored, should be kept dry. The footwear of all personnel should be scrubbed using a disinfectant solution and a stiff brush before entering the area.

Key plant personnel should be trained as security safety officers to be certain that sanitary guidelines are carried out. A feed and processing company in Maine uses the following control practices. Thoroughly clean between flocks using 400-lb pressure spray rig, disinfectant and fumigation, if possible. No feed is carried over between flocks; elimination of manure piles, bird-proofing buildings, locking doors, and rodent control are carried out; servicemen practice thorough disinfection between farms to avoid disease-carrying problems; personnel and equipment are sanitized thoroughly when leaving a farm and before going to another. Many of the same bacterial diseases and parasites that affect chickens also affect wild birds. Sparrows, cowbirds, and starlings are the most likely carriers, but many other species are infected. By discontinuing ranges and building windowless and bird-proof houses, the hazard of bringing in infection is reduced.

Poultrymen located in heavily populated suburban areas must accept certain responsibilities concerning their operations as they affect their neighbors. Avoid nuisance problems by keeping your farm neat and clean. If manure must be stored, see that it is well away from the neighbors' homes. Use discretion in the timing of cleanout operations. Haul manure during the early morning in cold weather, and avoid hot muggy days. If you have a lagoon, watch overflow outlet. Lagoons should be located so there is no possibility that manure can contaminate the stream. Follow a sound fly and rodent control program, and local health laws in the disposal of dead birds and explain to neighbors how dead birds are disposed of.

Gamma radiation has potential value in destroying insects and bacteria in feedstuffs. Food and Drug Administration has approved the use of gamma radiation in processing wheat and wheat products. The use of radiation is expected to grow and include many food items and become an important technique in the feed industry in a decade. At present, the process is too costly for animal feeding, but it is anticipated that it will find limited use with specific items and become more economical as time goes on.

A partial breakthrough in insect control may be coming. The structure of the long elusive insect juvenile hormone has now been chemically synthesized and is being applied. Insect control may be achieved with as

little as a gram per acre. Since treated larvae do not mature or pupate, ecological suicide occurs in northern climates. It is not likely that insects will develop resistance against their own hormone system.

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Poisons

INTRODUCTION

Harmful agents may be present in a feedstuff or gain entry at any step of processing and handling from the source to the final destination. Seeds of poisonous plants can have deleterious effects, such as lowered feed value, even though present in less than toxic amounts. There are large numbers of such toxic plants and some may be present in small grains (mustard in oats, cockle in wheat, ergot in rye). Cocklebur and nightshade are often present in soybeans. Some lots of corn shelled in the fields are loaded with jimson weed, cocklebur, nightshade, and milkweed seeds. Oats and barley are sometimes contaminated with wild flax and other noxious seeds. Sometimes good feeds are stored under conditions that promote rapid deterioration due to high moisture, high temperature, insect infestation, and storage near active poisonous chemicals. A serious contamination is that of rodent contamination of stored grains which may contain such pathogenic organisms as *Salmonella* or *Leptospira*.

Disinfectants, fungicides, insecticides, and certain agents deliberately added to certain seeds may cause trouble. Surplus seed treated with insecticides and fungicides has on occasion accidentally slipped into newly harvested wheat and gained entrance into poultry rations with disastrous results. Chickens sicken, die, or show no effects at all, but store the poison in their tissues or secrete it in the eggs causing residues in food products destined for human use. How well poultry tolerate an excess intake of a given toxicant is complicated by many factors, namely the amount of the element consumed, the period of time over which it is consumed, the interrelationships with other substances competing in absorption and excretion, rate of absorption and excretion, its accumulation in vital organs, nutritional and disease condition of the birds, chemical form of the element, and age and kind of fowl.

A poison is a substance which upon ingestion, inhalation, absorption, application, injection, or development within the body in relatively small amounts produces injury to the body by its chemical action. Toxicity is the quality of being poisonous. Toxicity may be mild, severe, chronic, subacute, and acute. An acute toxicity may be lethal or fatal to the animal. The most prevalent kind of toxicity in poultry, however, goes unnoticed and generally results in poor or mediocre performance in regard to growth, egg production, egg quality, and efficiency of feed utilization.

Tolerance is the ability to endure a given intake of a toxicant without significant depression of performance.

Although trace minerals are necessary for the proper nutrition of poultry, they can be toxic to the animal if an excess is consumed. The accompanying table shows the requirement, tolerance, and toxic level of trace minerals for poultry. It is obvious that there is a wide margin of safety between nutritional requirements and the toxic levels of the trace minerals, especially for zinc, manganese, iodine, and copper. Since the addition of molybdenum or selenium to poultry rations is not permitted by the Food and Drug Administration, accidental poisoning by excessive levels of these minerals is unlikely. The addition of a small amount of trace minerals is sound; excessive levels may be disastrous.

LIMITATION OF AMOUNT OF WEED SEEDS

Toxicants frequently occur in weed seeds. Federal law prohibits interstate shipments of grain containing noxious weed seeds, but permits unrestricted shipment of feed grains, hay, straw, and feed mixtures containing seeds of such weeds. Noxious weed seeds come to the United States from all points of the world. Many states have no antiweed laws or only ineffective ones. Incorporation of screenings in formula feeds is considered particularly dangerous from the standpoint of spreading weeds. The present allowance of 2% dockage from grain values for weed content is virtually an invitation for grain handlers to see that 2% of screenings is present. Weed seed may be added to clean grain in order to ship the 2% of screenings permitted by law. No feed man should be a party to any practice that is costing farmers several billion dollars a year. Methods should be established to make it impossible for weed seeds contained in feeds to germinate, and to render imports of screenings and whole grains harmless. It has long been known that seeds of many noxious weeds may be spread in the droppings of grazing animals. When seeds pass through cattle, conditions may cause an increase in promptness of germination.

Cockle

Cockle is usually found in wheat—the percentage runs from none at all to 2%. Corn cockle contains a toxic substance known as tithagin, a saponin-like glucoside listed as a hemolytic poison. It is destroyed by heating to 482° F. Young animals are more readily affected than older animals. A ¼ lb of corn cockle per 100 lb of live weight is harmful to the fowl; toxic dose is 0.2% of the body weight. Corn cockle seed consumed to the extent of 0.005 to 0.01 gm daily poisons young chicks. Birds affected with the toxic principle present a generally listless and unkempt appearance, a pale comb, staggering gait, difficulty in breathing, and marked diarrhea. Postmortem

examination shows the presence of a yellow caseous lining of the crop, an amber gelatinous exudate next to the outer muscular coat of the crop, and similar material within the pericardium of the heart, hemorrhages or congested areas in the fatty portions of the heart, a clear fluid surrounding the intestine, and some congestion in the lungs and trachea. Body temperature and total blood count are not affected. When fed in the whole form, the cockle is not as toxic as when ground.

Ergot

Ergot is a fungus *(Clavicets purpurea)* which develops on rye plants and causes powerful uterine contractions and contractions of the muscles of the intestinal tract. It reduces and often interrupts blood circulation in the feet and legs. Symptoms include nervousness, sensitive skin, muscular trembling, incoordinated gait, and convulsions which may lead to death. Animals go off feed, become dull and depressed and often their lower legs will be stiff and sore. There may be a dry gangrene of the comb, wattles, and beak from poor circulation. Management measures consist primarily of using ergot-free feed.

Algal Poisoning

Algal poisoning has occurred in many parts of the world. The blue-green algae on a pond is without adverse effect, but when the algae bloom and turn the water red, the algae are highly toxic to animals. Animals show signs of convulsions, dyspnea, and paralysis of the extremities. Death occurs in 1 to 48 hr. The toxic principle is not well understood.

Limonin

Citrus seed meal, a by-product of the citrus canning, is potentially a valuable ingredient for chicks since it contains 33% protein, 5% fat, 8% fiber, and 6% mineral content. Experiments have demonstrated, however, that, as now prepared, this by-product is unsatisfactory for chicks. High mortality results during the first three weeks causing enlarged gall bladders and sometimes mottled liver, ascites, and congestion of the intestinal tract. The deleterious factor is a white crystalline compound soluble in acetone and 95% ethyl alcohol, but insoluble in water and diethyl ether. Analysis showed it to be limonin, the bitter principle of the seed.

Scurvy-like Condition

Some fishmeals stored for a long period induce a condition in chicks which has been described as similar to scurvy in appearance. It is believed to be an intoxication induced by nitrogenous bases. There is a profound increase in blood-clotting time.

Lathyrus

Many varieties of peas and beans have been cultivated from remote times as food for man and domestic animals. One exception has been *Lathyrus sativa* which is harmful to farm animals. Large agricultural populations in some parts of India used to subsist to some extent on *Lathyrus* peas and were affected by paralysis of the lower limbs. In poultry, *Lathyrus* poisoning causes changes in the nervous system, ascites, and severe bone abnormalities.

Gossypol

As discussed elsewhere, cottonseed products are a source of two toxic materials. Gossypol causes depressed growth rate in chicks, poor hatchability of eggs, and discoloration of egg yolks. Cottonseeds also contain cyclic fatty acids which are capable of producing marked discoloration of the albumen of the eggs. Inasmuch as cottonseed oil is sometimes used in poultry diets as a source of energy, the possibility exists that this might become a field problem. Soybean meal, the very foundation of modern poultry feeds, cannot be successfully used without heat treatment to destroy an inhibitor. The toxic material contained in raw soybeans is of interest today because of attempts to use raw whole soybeans in feeds.

Crotalaria

A serious problem developed in certain flocks in South Carolina in 1959 due to *Crotalaria* toxicity and a change in the method of harvesting corn. *Crotalaria spectabilis* had been widely planted on the ill-advised recommendation that it be used as a hardy cover crop. As little as 0.2 lb of *Crotalaria* seed per ton of complete feed is toxic to chicks, and growth retardation occurs at levels as low as 0.01%. The use of combines for harvesting corn brought about simultaneous harvesting of *Crotalaria*. When *Crotalaria* is consumed, excess fluid accumulates in the pericardial sac and peritoneal cavity. There is a blotchy hepatitis and occasional hemorrhages in the liver, heart, and musculature.

Ethylene Dibromide

Researchers in the South complained of a decreasing egg size in 1957 at a time of the year when it would normally be expected to be increasing. Investigation proved that the source of the problem was the fumigant used on oats. The fumigant contained ethylene dibromide, one of the components which has been shown by workers in Israel to cause reduction in egg size after feeding for a period of seven weeks duration.

Rapeseed Meal

Rapeseed meal contains a goitrogen and attempts to inactivate this factor have not been successful. Alfalfa meal contains a saponin which causes growth inhibition. Aortic rupture in turkeys can be produced by feeding certain legumes such as sweet peas which contain beta aminopropionitrile (BAPN). Some weed seeds contain substantial urease activity. While not necessarily toxic in itself, it can cause a rapid loss of nitrogen from feed which contains urea. Feed manufacturers should guard against toxic weed seeds.

Oxidative Rancidity

Linoleic acid content is related to the tendency of low vitamin E diets to produce encephalomalacia. Unsaturated fatty acids cause vitamin E deficiency symptoms. This effect is unrelated to the oxidative rancidity of dietary fat. Another factor is the presence of harmful quantities of nitrates in feeds. High nitrate content interferes with the conversion of carotene to vitamin A. All plants are likely to accumulate considerable nitrate if they are grown on high nitrate soils. The stinging nettle and the elderberry accumulate nitrogen regardless of the type of soil on which they are grown.

A word of caution about heat treatment is also in order. It is generally recognized that excessive heat treatment impairs protein quality. Much of this may be due to the browning reaction between amino acids and reducing sugars.

Some feeds contain toxic materials which have been identified chemically and investigated pharmacologically. Among these are goitrogens, namely cabbage, cauliflower, cyanogens in various beans and nuts, solanins in potatoes, and neurotoxins in various species of seafood. Two organic seed protectants are Arasan and Orthocide.

PESTICIDES

It has been estimated that from 15 to 50% of all farm products in various regions of the world are destroyed by insects and other pests before being consumed. Chemical pesticides are used to prevent this waste. The use of chemical pesticides carries some degree of risk. Against this risk, however, the need to supply enough food for a rapidly growing world population and to use every means available to conserve and protect for human use such crops as we are capable of producing must be weighed. Many alternatives to the use of chemical pesticides have been proposed by protectionists and ecologists, many of whom seem to value wildlife and birds more than human needs.

Insecticides make up the lion's share of the pesticides produced but herbicides have increased in recent years from 17 to 22% of the total.

Fungicides represent about 10% of the market and include soil fumigants. conditioners, and animal dips. The introduction in the early 1940's of 2,4-D although aimed at only eliminating broad-leafed plants was the first large-scale effort to control weeds by other than mechanical tillage. About 40% of the pesticides sold are for the farm; 40% are bought by other domestic outlets, and 20% are shipped abroad.

Since the practice of treating seed grains with chemicals for the control of diseases has become quite general, there are often considerable quantities of treated grain which for one reason or another are not used for planting purposes. Experiments at Cornell University showed that of 3 chemicals used to treat corn seed, 1 caused a decided drop in egg production when fed to hens as ⅓ of the ration. Production dropped from 70 to 10%, 2 to 3 days after feeding. Two mercury compounds had no adverse effect. In research in Texas, ¼ of a broiler flock exhibited hock and leg disorders (perosis and spraddles) when fed diets containing as low as 4 to 100 ppm TMTD. Growth rate was also markedly decreased. Laying hens dropped to zero production after being fed treated grain for two days.

A goodly part of the tremendous production of feed and food in this country is the result of the use of pesticides of one sort or another. Many of these chemicals are poisonous whether eaten by grasshoppers, rats, or humans. Pesticides are applied to feeds and if people ingest enough of them they have the potential of acting on us as they do on poultry, flies, or cutworms.

POISONOUS PLANTS

Poisonous plants contain or produce toxic substances in amounts sufficient to harm animals. A plant may contain one or more of the following substances that are themselves toxic such as alkaloids, resinoids, phytotoxins, and oxalic acid.

A second category of substances are themselves harmless but decompose to form toxic products either before or soon after they are eaten. For example, the nontoxic glucoside amygdalin produced in choke cherry changes during digestion to form highly toxic prussic acid.

A third group of substances are those formed by the action of microorganisms on plants or plant products. Fungi under certain conditions produce moldy hay or silage, forming decomposition products which may be toxic.

Fourthly, toxic substances may be absorbed from the soil and stored in harmful quantities in tissues of certain plants. Selenium and potassium nitrate are two of these substances.

Fifthly, there are substances that cause photosensitization. Certain

TABLE 33.1

RANGES AND AVERAGES OF INSECTICIDE RESIDUES FOUND IN FEEDS

Insecticide	% Contaminated	Range of Contamination	Avg. Level of Contamination
		(Ppb)	(Ppb)
Gamma-BHC	100.0	5–79	16.0
Aldrin	86.1	1–16	2.6
DDT	98.0	10–448	80.5
Methoxychlor	45.5	10–580	74.0
Endrin	58.4	4–27	10.6
Chlordane	67.3	5–254	30.4
Dieldrin	88.1	1–16	4.9
Toxaphene	14.8	60–530	178.3
Heptachlor	8.9	2–13	4.8
Heptachlor epoxide	3.0	1–6	3.3

Source: Minyard and Jackson (1965) J. Assoc. Offic. Agr. Chemists 46, 843–859

plants contain a pigment which is absorbed through the intestinal wall into the circulatory system and is not eliminated. This substance causes the light or unpigmented areas of the animal body to be sensitive to light.

Turkeys

INTRODUCTION

Turkeys are natives of the New World and were recorded in history when Cortez landed in Mexico. They greeted the Pilgrims when they landed at Plymouth Rock and were served for their first Thanksgiving feast in the New World. In the early part of the twentieth century, Naragansetts, White Hollands, Burbon Reds, and Standard Bronze turkeys were kept on small farms and virtually no improvement in breeding was made. Between 1930 and 1940, great improvements were made in the Broad Breasted blood lines. Breeders are now developing pedigreed stock by strain and cross breeding, even 3- and 4-way crosses, so that the quality of breeders is far better than it once was. Today's Broad Breasted turkey strains are possible only through artificial insemination. Turkeys with a conformation and meat yield that satisfies the processor and consumer have neither the agility nor desire to mate as often and successfully as the narrow-breasted turkeys.

A few years ago, the turkey industry was a four-month, dressed bird market for Thanksgiving, Christmas, and New Years. Today, turkeys are processed the year around and the housewife can serve turkey any day of the year. Poults are brooded in insulated pole barns and put on range at 8 to 12 weeks of age. Two acres of range are provided for each 1,000 birds. Feeders, waterers and shelters are movable and the birds rotated to new range until they reach market size.

Almost half of the turkeys consumed in the United States are produced in the North Central area of this country because of climate, economy and availability of feeds, improved feeds, disease control, management practices, and marketing advantages. Turkey production has increased more than fivefold since 1929.

BROAD BREASTED BRONZE TURKEYS

Broad Breasted Bronze birds are produced because of their large, mature body size and the greater profit per head in comparison with smaller birds. Broad White turkeys are grown also and have the advantage of white pin feathers which result in improved carcass appearance. Turkey growers predict that the Broad White will completely replace the bronze-colored bird in the future. Increased use of bulk handling equipment, mechanical feeding and watering, and other labor-saving devices, including pole-shed housing have been responsible for the efficient manner in which the birds

are raised. It permits the producer to grow larger flocks. In recent years, many producers have concentrated on the production of turkey broilers, most of which are reared in confinement. Increased production necessitates greater production of breeder hens and increased hatchery production. The dynamic growth of the turkey industry has doubled per capita consumption during the past 20 yr.

NUTRITIVE REQUIREMENTS OF TURKEYS

The turkey's requirement for vitamins A, D, niacin, and choline is substantially higher than for the chick. The other vitamin requirements are similar, except vitamin B_{12} which is three times higher for the chick. Vitamins routinely added to rations of turkeys include A, D, E, K, riboflavin, pantothenic acid, niacin, B_{12}, and choline. In recent years, there has been evidence of a biotin deficiency in turkeys fed corn-soybean type diets. At least, biotin has been helpful in correcting the trouble. Researchers have not, as yet, identified all the variables involved in this problem. Many turkeys have been raised without biotin supplementation with no biotin deficiency signs. Possibilities suggested as causative agents include usage of certain drugs, improperly heated soybean meal, consumption of wild seeds, molds, genetic changes, and nutritional imbalance. Biotin is added to the ration to prevent dermatitis on foot pads.

Margins of safety are necessary for certain of the vitamins. This is partly because certain vitamins have a beneficial effect at higher than requirement levels under disease or nutritional stress conditions. The vitamin fortifications for turkey rations have changed as the cost of synthetic vitamins has decreased. As a result, there is no need to risk borderline vitamin deficiencies during periods of stress or depressed feed intake. Synthetic thiamine, folic acid, and biotin are sometimes added to turkey rations, since research has indicated that practical turkey rations may be deficient in these. As previously stated, some practical turkey rations appear to be deficient in biotin because symptoms and lesions observed are dermatitis on the bottom of the feet, reduced growth rate, and general unthriftiness.

Selenium Deficiency

A recent discovery is that a selenium deficiency may also be a practical problem with turkeys. Poor growth, gizzard myopathy, and high mortality occur if the deficiency is severe. Most soils east of the Mississippi River are deficient in selenium. The selenium requirements of poults are estimated to be 130 to 150 mcg per lb of feed. The Food and Drug Administration does not sanction the addition of inorganic selenium to feeds. However, turkey producers use selenium-rich feed ingredients such as wheat mill by-

products, standard middlings, and mill-run wheat from wheat grown in selenium-rich areas.

Mineral Supplements

It is common practice to supplement turkey feeds with calcium, phosphorus, and zinc, as well as iron, copper, and iodine. Poults are frequently slow to learn to eat. Outbreaks of rickets have been traced to inadequate intake of rations normally adequate in calcium and phosphorus. A zinc deficiency can also occur with practical rations. Symptoms are enlarged hocks and poor feathering.

Feeds for Turkeys

Feed is by far the largest single item of cost in producing market turkeys. The selection of the rations which are more efficient from a nutritional and economic standpoint, therefore, is one of the most important management decisions facing the market turkey producer. Rations fed to market turkeys during the growing and finishing period usually consist of a broiler or starting mash and a mixture of whole grains. The choice of the grain depends on its availability, cost, and nutritive value. In recent years, milo and kafir have been in abundant supply and priced lower per pound than corn. There is usually an abundant supply of oats and this crop is priced low during the late summer and fall months in certain areas.

Antibiotics

Potentiated antibiotics are used in starter rations; this reduces mortality and enables poults to put on weight early when the gains are least costly. Antibiotics protect against paratyphoid, PPLO infection, blue comb, hexamataxiasis, and synovitis; antibiotics also overcome infections during stress periods, including vaccination, moving, handling, and weather extremes. Automation of feeding and watering is common. Clay-type floors are covered with woodshavings. There are three broods a year. There is a cleanup of houses and equipment between each brood. As many as 2 million birds are grown each year on some turkey ranches and they market over 90% of all poults started.

MARKETING OF TURKEYS

In the United States, the Thanksgiving market is the largest, but there is also a very substantial one for Christmas.

The average yearly consumption of turkey per person in the United States has risen from 5.9 lb in 1957, to 7.7 lb in 1966, and 8 lb in 1967. Freezing the whole turkey and turkey parts encourages the consumer to buy turkey meat the year-round and institutions are making wide use of

turkey rolls. Years ago, 32 weeks were required to market turkeys; today they are ready in 24 to 25 weeks with an average weight of 26 to 27 lb for the tom turkeys and 18 lb for the hens. Turkeys weighing 70 lb have been produced but these are not common. In their natural state, turkeys lay eggs only 6 or 7 months of the year. By keeping the gobblers in windowless houses and varying the lighting, it is possible to stimulate egg production 1 or 2 months early and to have egg production the year-round (not from the same birds).

EFFICIENCY OF FEED CONVERSION

Turkey hens and toms can be produced experimentally with an efficiency of feed conversion of 1.85 to 2.25 lb of feed per pound of turkey, respectively. Great advances have been made in the last several decades in turkey production as a result of the advances in turkey nutrition and practical application of these findings in the field. Still much of the knowledge was obtained by trial and error and more precise knowledge is necessary. Under present methods of feeding, at least 1/5 of the protein fed to turkeys is wasted. Until recently, the protein and amino acid requirements were expressed as a percentage of the ration, without any consideration being given to the energy level or the feed intake. The importance of relating the protein and energy requirements of the ration is obvious. The energy level regulates the amount of feed consumed. When rations containing different energy densities are fed to turkeys, there is no difference in the daily energy intake per turkey. Birds fed a low calorie ration consume approximately twice as much feed as birds fed high calorie rations. The environmental temperature, sex, and strain of birds also affects protein requirements and must be considered in formulating turkey rations. Prolonged hot or cold weather causes a decrease or increase in energy intake of 15 to 25% from the normal intake at moderate temperature.

The National Research Council requirement of poultry lists the protein requirement of starting poults at 25% of the ration and growing turkeys of 8 to 16 weeks of age at 20%. These recommendations apply to rations containing 1,110 Cal of metabolizable energy per pound for the starting poults and 1,180 Cal for the older birds. If high levels of added fat are used in the ration, higher levels of protein are necessary for optimum growth.

In high-protein corn or milo soy-type rations, the first limiting amino acid is methionine; the second lysine. In low-protein rations, lysine is the first limiting and methionine is second. In low-protein rations much of the protein is derived from grains which are poor sources of lysine. It is cheaper at today's prices to add synthetic methionine than to increase protein. A multiple amino acid deficiency occurs when the protein in the starter ration is reduced to 24% or lower.

Turkey Rations

Energy accounts for a large part of the cost of the turkey ration. For many years, turkeys were fed low energy rations. As much as 30% of a ration would consist of wheat bran, wheat middlings, and alfalfa. As feed grade fats became available economically, from 2 to 8% fat was added to produce medium to high-energy rations. The common practice is to start broods on rations containing 1,200 to 1,300 Cal of metabolizable energy per pound. This is increased during the growing period with the birds being finished on rations containing 1,500 to 1,600 Cal per pound. The cost per calorie is not the only factor to be considered as the time required to obtain market weights and the carcass finish of the bird must be considered. Energy from fat is more efficiently metabolized than that from carbohydrates. The explanation is that there is a ceiling on the energy needed to synthesize tissue fat from carbohydrates. As the level of added fat in the turkey ration increases from 2 to 8%, the feed efficiency increases 14%.

Years ago, turkeys were fed somewhat as follows: poults were fed wheat bread soaked in milk, squeeze-dried and mixed with egg and sting nettle chopped fine. In the morning they were fed lettuce and at night sting nettle with bread soaked in milk, and a little chopped onion. They were given all the skim and sour milk that they would drink. In the 1930's it was discovered that blackhead was due to a microorganism carried by chickens and transmitted to turkeys. It rarely caused disease in chickens but was disastrous when outbreaks occurred with turkeys. Thus, turkey growers began to raise turkeys in confinement. This greatly reduced mortality due to blackhead but with it came many nutritional problems. Confined turkeys no longer had access to the lush, green pastures and many of them grew poorly. A large percentage became crippled.

TURKEY PRODUCTION

Turkey production in the United States has increased rapidly. In 1948, there were only 31 million turkeys; in 1952, 60 million; in 1968, a record of 80 million turkeys were produced. A primary reason for the phenomenal increase is that turkeys are now produced at a cost which provides high quality meats for the consumer at low cost. Feed manufacturers wasted no time in translating research findings into improved turkey feeds which resulted in faster and more economical returns to the commercial turkey grower, thus enabling them to provide meat at a reasonable cost to the consumer. Prior to 1948, most turkey rations contained high-fiber, low-energy ingredients such as wheat bran, alfalfa meal, and oats. More recent research has shown that many of the problems starting poults encountered were because such rations are not palatable to young turkeys. Starveouts

and uneven rates of growth and poor feed efficiency result. Earlier difficulties in getting poults to eat were largely eliminated by the use of high-energy rations. These rations also markedly improved the efficiency of feed utilization. Thus, improvements in turkey nutrition over the years have resulted from research on energy and protein levels.

RESEARCH ON TURKEYS

Antibiotics and UGF have been important fields of research also. For the future, more precise information is needed concerning the exact proper balance of energy, protein, amino acids, vitamins, minerals, antibiotics, enzymes, and hormones. More information is needed also on digestibility of feedstuffs, stress, disease, vaccination, and moving birds. As science learns more of the potentialities through optimum methods of breeding, management and feeding, the turkey will become one of the best converters of feeds into highly nutritious foods.

Manganese and choline are concerned in the prevention of perosis in turkey poults. Riboflavin, pantothenic acid, niacin, vitamin B_{12}, vitamin A, vitamin D, and choline are now routinely added to turkey feeds by feed manufacturers. Antibiotics improve growth when fed to young turkeys. Growing turkeys have the highest protein requirements of any class of poultry or livestock. There is a belief among certain turkey growers to the effect the turkeys need rations high in fiber during the growing period after the first eight weeks. Such theory is without foundation in the light of experimental evidence. Present evidence indicates that it is not good practice for turkey raisers to use feeds that are high in fiber during the growing period. Excellent turkeys are raised on feeds that are low in fiber and high in energy. Vitamin A is one of the critical vitamins in the practical feeding of turkey poults and a source of this vitamin should be added to the feed by the feed manufacturer either in the form of pure vitamin A, vitamin A from fortified fish oil, stabilized vitamin A in the form of a dry vitamin A concentrate or carotene (provitamin A). Vitamin A is necessary for growth and for maintenance of the inner linings of the digestive, respiratory, reproductive, and other similar surfaces in the body of the poult. Most feed manufacturers meet this requirement by using high grade, dehydrated alfalfa leaf meal, and supplementing with one of the forms of vitamin A.

Vitamin D_3 or activated animal sterol is the best form of vitamin D to use for feeding turkey poults. It is utilized more efficiently and assists in the utilization of phosphorus to a greater extent than vitamin D from fish oils. Vitamin D is not required if poults have access to sunshine but feed manufacturers cannot take the risk of eliminating vitamin D in the hope that

birds will be grown in sunshine. Brewers' dried yeast is effective in preventing hock disease "even when the diet contains 2% fish oil."

CURLED TOE PARALYSIS

"Curled toe" paralysis is a condition where poults sit on their hocks with their toes curled inwards and is a symptom of a deficiency of riboflavin. Since only small quantities of this vitamin are found in feeds normally used in turkey rations, riboflavin should be added to the feed to ensure that a riboflavin deficiency does not occur. Pantothenic acid is required for the prevention of dermatitis or sores at the corners of the mouth, on the eyelids, and on the tops of the feet. It is required for growth and maximum utilization of feed. Pantothenic acid deficiency has occurred in a few instances in the field.

CONDITIONS FROM NIACIN DEFICIENCY

Niacin deficiency symptoms in turkey poults are similar to those described for chicks: namely, perosis, poor feathering, poor growth, and inflammation of the tongue. The addition of niacin to a turkey feed is more important with high energy rations, composed largely of corn and soybean meal. Wheat by-products are good sources of niacin and if they are removed in an attempt to increase energy content, niacin should be added to the feed. Choline is required for the prevention of perosis or slipped tendon in turkey poults, as well as for growth and good feed utilization. Soybean meal is an excellent source of choline, but is usually added also as choline chloride feed supplement. Growing poults have a sufficient amount of vitamin B_{12} carried over from the mother through the egg. The poults respond to vitamin B_{12} supplementation of the ration when antibiotics are fed to produce maximum growth.

CONDITIONS FROM BIOTIN DEFICIENCY

Antibiotics increase the growth rate of turkeys from 5 to 25% when fed an all-vegetable-protein ration. Aureomycin, bacitracin, and penicillin are used for growing turkeys and give good results. Perosis or leg weakness in turkeys occurs from a biotin deficiency. The biotin requirement of the turkey is approximately 2½ times as high as that of the chick. The young poult consumes approximately 20 gm of feed per day during the first 2 weeks of life. The starter diet must contain 0.25 mg of biotin per kilogram in order to provide 6 mcg biotin per poult per day. Biotin that exists in natural materials occurs in both bound and free form, but much of the bound biotin is unavailable. Synthesis of biotin in the intestinal tract supplies a variable and undependable amount of biotin for the nutrition of poults.

Further, diets that have become rancid lose biotin. Brewers' dried yeast is one of the best natural sources of biotin. It consistently improves the appearance and condition of the legs of turkeys.

FEEDING METHODS

Methods of feeding turkeys were adapted from those for chickens. The mash and grain or pellets and grain systems in which the feed is kept before the turkeys all the time are the most popular methods. Increased production and the lower selling price of turkeys have created greater interest in the methods of feeding turkeys to secure lower cost of production. The term "concentrate" or "free choice" feeding of turkeys is applied to two different methods of feeding. In one method, the high protein concentrate is fed and supplemented with whole grains kept separate in the same

TABLE 34.1

GROWTH RATE AND FEED CONSUMPTION OF BROAD BREASTED BRONZE AND WHITE TOMS

Age in Weeks	Live Weight		Feed Required	
	Avg	Gain for Period	Total Cumulative	Per Pound of Turkey to Date
	Lb	Lb	Lb	Lb
1	0.27	0.15	0.2	0.75
2	0.55	0.28	0.6	1.1
3	1.00	0.45	1.2	1.2
4	1.50	0.50	2.1	1.4
5	2.1	0.6	3.4	1.6
6	2.8	0.7	4.8	1.7
7	3.7	0.9	6.7	1.8
8	4.7	1.0	8.8	1.9
9	5.8	1.1	12.1	2.1
10	6.9	1.1	16.2	2.3
11	8.0	1.1	20.6	2.6
12	9.2	1.2	25.0	2.7
13	10.5	1.3	29.5	2.8
14	11.8	1.3	34.3	2.9
15	13.1	1.3	39.0	3.0
16	14.6	1.5	43.8	3.0
17	16.1	1.5	48.5	3.0
18	17.6	1.5	52.9	3.0
19	19.1	1.5	57.5	3.0
20	20.6	1.5	62.5	3.0
21	22.2	1.6	67.7	3.1
22	23.8	1.6	74.0	3.1
23	25.4	1.6	80.5	3.2
24	27.0	1.6	87.3	3.2
25	28.5	1.5	94.0	3.3
26	30.0	1.5	100.0	3.3
27	31.3	1.3	107.0	3.4
28	32.5	1.2	116.0	3.6

hopper. In the other, the high protein concentrate is mixed with ground grains to approximate the composition of commercially prepared mash.

Hen turkeys mature at an earlier age than tom turkeys. It is most economical to begin feeding a finishing diet high in energy and low in protein to hens at about 16 weeks of age and market them as soon as they show a satisfactory degree of finish. Tom turkeys are still growing rapidly at 8 weeks of age and are fed growing diets until they are approximately 21 weeks of age before giving them the high-energy, finishing diets. By reducing the protein and increasing the energy content of the feed approximately three weeks before marketing, toms are finished at an earlier age and lower weight than they would ordinarily achieve at maturity. Common vegetable and animal sources of protein are combined to provide the essential amino acids in approximately the ratio required by turkeys and higher use is made of synthetic methionine, lysin, and other amino acids when the need arises. Both growth and efficiency of feed utilization are markedly improved by this adjustment.

NUTRITION OF BREEDING TURKEYS

Insufficient research has been done on the nutrition of breeding turkeys. For high hatchability of fertile eggs, turkeys require very high levels of vitamin E. Fresh grass juice produces a marked increase in the hatchability of fertile eggs, but apparently this is not due to its vitamin E content. Turkey breeders require more pantothenic acid than is needed for breeder chickens. Vitamin A is very important, particularly for its carryover values to the young poult at hatching time. Improvements in the efficiency of feed utilization have had much to do with keeping turkey producers in business. There are slight variations in fertility as a result of nutrition in turkey breeders.

An all-vegetable diet results in a slight reduction in numbers of copulations and fertility by single males. A ration low in vitamin A reduces sperm development. Vitamin E deficiency affects sperm development and activity, and feed restriction gives a pronounced decrease in fertility and semen volume in males. Excessively fat toms are relatively inactive and clumsy in mating. Sexual maturity in turkey toms varies from 20 to 38 weeks, with the average around 30 weeks. Artificial lights affect sexual activity and sperm development. Mating precedes the onset of egg production so it is important that toms be subjected to artificial light ahead of the hens. Frequency of mating is usually highest just prior to egg production and declines as egg production reaches its peak. The highest degree of fertility is observed during January, February, and March. Sudden changes in temperature have a definite effect on fertility. Preferential mating is another factor that affects fertility of single tom matings as well as large

flock matings. Under good management, a season's fertility rate of 85% can be expected.

After the toms and hens have been selected they are placed on special feeds providing them all of the nutritional needs of breeder birds. The feed should have additional levels of essential vitamins and trace minerals to supply any deficiencies that have occurred during the growing period. The grain is reduced as much as possible to prevent accumulation of fat on the birds prior to going into the breeding pens. If grain is fed, it should be good quality oats. Green feeds should be made available when possible during the interim between the time birds are selected and blood tested until the time they go into the breeding pens. If early egg production is to be expected, toms are placed under artificial lights at least three weeks prior to placing them in the pen with the hens. This stimulates the less active toms and it insures greater activity at the time mating begins. Lights are turned on at 4:00 A.M. In the breeding pen use 1 tom for every 20 hens. Spare toms should be kept on the breeder diet and under lights when they are in the resting pens.

Breeders should be fed a complete breeder pellet with all grain feeding eliminated. This provides uniform feed intake. Do not mix toms from one group with toms from another. Keep each group separate during the breeding season as a precaution against fighting. This permits rotation and a spare group to give an opportunity to rest the birds. The breeder feed should be fed 30 days before egg production is expected. Protect the birds against rain and cold. Sudden drops in temperatures do more toward reducing fertility than the actual cold and rain. Remove broody birds from the nest each night and place in separate pens on the breeder feed. Hatching eggs should be gathered three times a day during extremely cold weather. The eggs should be allowed to cool before being placed in cases. If the eggs are to be held they should be turned to prevent damage to the germ. Low fertility is a baffling and costly problem in turkey breeding operations. Both fertility and hatchability tend to decrease rather rapidly as the breeding season progresses, particularly in out-of-season hatching. Age and staleness of sperm influences hatchability of eggs. More frequent matings might result in higher hatchability of turkeys. Fertility is improved by artificial insemination either alone or in conjunction with natural matings. The late season decline of fertility of naturally mated females is reduced by artificial insemination during the last six weeks of their breeding seasons. Turkeys produce semen of about half the volume (0.33 ml) and twice the sperm concentration (8,400,000 per cu mm) as chickens. Increasing the interval between successive inseminations from 2 to 4 or 6 weeks results in lower fertility, hatchability, and egg production. There is no significance in either degree or duration of fertility and hatchability between

groups of females inseminated with a single dose of semen of different concentrations. Since turkeys produce relatively small amounts of semen, these results suggest that more efficient use of the semen might be made by utilizing smaller doses.

SPECIAL REQUIREMENTS

Differential feeding cuts turkey costs. Turkey toms need a higher protein content in their finisher ration than hens to achieve maximum economy and weight gains. Feed costs can be significantly reduced by adopting a different dietary regime for the sexes after birds are eight weeks old. Best economic response from toms is obtained on a finisher feed containing 21% protein. The optimum return from hens is obtained on an 18% protein ration. This is logical because toms grow 30 to 35% faster than hens. Rearing the sexes separately on different feeds saves at least 5¢ a bird. Turkeys require more protein than chicken broilers, particularly during their early starting-growing period. Soybean protein is adequate in most respects for good growth but somewhat deficient in some amino acids compared with animal proteins. High quality fishmeal is frequently added during the starting and growing periods of the poults. Since corn supplies more energy than either oats or barley, producers make maximum use of corn in turkey fattening, finishing, or breeder hen diets.

Growth Rate Control

Growth rate of turkeys can be limited by restricting feed consumption to 70% of the amount consumed by full-fed birds, feeding high-fiber oats hulls, or a ration containing a chemical additive distasteful to turkeys. Restricted birds weigh 1 to 2 lb less than full-fed birds. Restricted birds at the start of egg production start to lay about 5 to 8 days later than the controls. Fertility, hatchability, and weight of eggs are not diminished by the growth restriction. In fact, restricted birds show a significant improvement in average fertility. Growth restriction of turkeys by means of restricting the nutrient intake leads to a decrease in the number of eggs laid. Therefore, it appears wise to feed young breeder turkeys conventional starter-grower and finisher rations that have been proved by past experience to be satisfactory.

Diet Protein Level Adjustment

If both methionine and lysine are available for feeding, the protein level could be reduced to approximately 20% by adding synthetic amino acids. This would give a diet relatively higher in energy and efficiency than a comparable 28% protein diet. But synthetic lysine, so far, is not available at sufficiently low cost for animal feeding, so it must be supplied from natural

sources. For practical purposes, a carefully selected protein mixture at approximately 24% level, properly supplemented with methionine presents the best possibility for top poult performance. Protein quality must be put ahead of protein quantity in the formulation of turkey diets. This is imperative in poultry rations in which the lysine requirement is high and increased energy is necessary to improve efficiency. It is evident that increased efficiency in turkey diets should come from the use of increased dietary energy levels properly balanced with all other nutrients. A 900 Cal, 24% protein diet of high quality (especially in lysine content) and supplemented with DL-methionine seems to be the best approach. The use of fat and 50% protein soybean meal are necessary under present conditions. As more knowledge is gained in regard to the poult's nutritive requirements, perhaps 24% protein diets at 1,000 Cal will become a reality.

Diet Adjustment in Hot Weather

During extremely hot weather it may be necessary to feed as much as 20% or more oats in place of corn to keep birds eating at full capacity. With cooler weather, corn should be fed as the chief grain for lower cost. Several additives may be included in a turkey mash. High levels of antibiotics or nitrofurans have been used to advantage during the first two weeks of life. Generally speaking, cost of these drugs become prohibitive if they are fed beyond the first few weeks. Control of certain types of intestinal or respiratory disorders are made by feeding these drugs for a period not to exceed 5 to 7 days. Organic arsenical drugs improve weight gains and feed efficiency when added to feed. A tranquilizer in the mash reduces blood pressure in turkeys, particularly between the 8th and 16th weeks of age to prevent aortic rupture. Antioxidants and coccidiostats are used in turkey feeds, and histostat and Hepzide (20%) for blackhead control. These drugs are added according to the manufacturers directions to avoid toxicity or excessive cost of medication.

For Broad Breasted Bronze turkeys, between 8 and 20 weeks of age, the minimum calcium requirement for maximum weight gains is 0.6% of the diet, and the minimum phosphorus requirement is 0.5 to 0.6% of the diet. Male and female poults differ widely in their protein and energy requirements. This may mean that each sex could be grown better separately and fed balanced feeds to fit their specific nutritive requirements if maximum growth and maximum efficiency of feed conversion are to be obtained.

Losses from Leg Weakness

It costs the turkey industry millions of dollars each year because of weakness and hock troubles in large tom turkeys. Leg weakness is not due to any single factor but results from a wide variety of different stresses, some

of which are pathological, others nutritional, still others genetic, and some from poor management. Leg weakness in turkeys may result from different diseases, 3 of which are nutritional and 2 pathological. The gross symptoms of these diseases are similar. At first, they have a stilted, unsteady gait with evidence of leg weakness. Soon one or both of the hock joints become enlarged and swollen whereupon the legs may bow or take on a knock-kneed appearance. In some diseases, it is noted that the Achilles tendon slips from its chondyl and typical perosis and enlarged hock disorders occur. Certain strains of turkeys are more susceptible to leg weakness than others. Weaknesses may be caused by breeding strains of turkeys with such a high ratio of meat to bone that its skeletal structure is no longer capable of supporting its weight. Poor footings on slat or wire floors, with no litter, may cause leg weakness at times when better flooring would produce normal birds. Thus, breeding, management, disease prevention, and nutrition are all important in prevention of leg weakness in turkeys.

Good management consists in preventing stresses, hock disease, mismanagement, and nutritional deficiency. Although brewers' dried yeast is relatively expensive compared to some other feedstuffs, it often seems justified if it prevents leg weakness in turkeys.

Losses from Crooked Breast

Crooked breast is of some economic loss in turkey production. There are several factors and combination of factors which cause the deformity. Heredity appears to be a factor. Thus, the careful selection of breeding stock appears to be of special importance. Feeding appears to have a more or less direct bearing on crooked breast production. Protein, green feeds, phosphorus, and calcium in proper amounts are especially important for the growing birds. Carbohydrates are probably a secondary consideration during the finishing period. An ample and convenient water supply at all times is important.

Late-hatched turkeys grow slowly during hot weather, but when more satisfactory growing conditions return they are able to overcome this retardation and obtain normal size at eight weeks. The amount of feed consumed per turkey varies from less than 2 lb during the 1st month to 20 lb during the 7th month. The amount of feed required to produce 1 lb of gain increases from 2.67 lb for the 1st month to 7.35 lb for the 7th month. Turkeys require rations that contain relatively high levels of protein. Since protein concentrates of animal origin are more expensive than those of vegetable origin, it is desirable to determine the relative value of these cheaper sources of protein in turkey rations. Within eight weeks after Bronze poults are placed on rations containing different vegetable protein supplements a marked difference in the color of the birds is observed.

Those receiving rations containing soybean meal develop plumage of the normal bronze color pattern, but poults fed rations containing corn gluten meal or cottonseed meal develop wing feathers which are almost white.

Quantitative Nutritional Requirements

The quantitative nutritional requirements of turkeys are higher than those of any other farm animal. They need approximately 1,200 to 1,400

TABLE 34.2

THE EFFECT OF A CHANGE IN PROTEIN LEVEL IN A POULT DIET ON THE ENERGY LEVEL AND THE RELATIVE AMOUNT OF METHIONINE AND LYSINE IT CONTAINS

% Corn	% SBOM	Prod. Energy	%	Methionine	Lysine
		Cal per Lb	Protein	% of Protein	
42	33	815	28	1.98	5.51
52	23	873	24	2.07	5.43
62	13	931	20	2.19	5.30

Cal of metabolizable energy per pound of diet and in addition, 13 vitamins, 13 inorganic elements, and 13 amino acids. Turkeys also need UGF present in such materials as soybean meal, distillers' solubles, brewers' yeast, and fish products. Because turkeys regulate feed consumption primarily to meet energy requirements, less feed is required to rear a turkey when diets of high energy value are used as compared to low energy feeds. Starting and growing rations should contain enough energy for maximum growth with no excessive amounts to be deposited as fat. Finishing diets should contain wider energy to protein ratios. When energy is in excess of that needed for growth, the extra energy is converted to fat.

TABLE 34.3

IMPORTANT TURKEY FACTS

	U.S. Avg Price Received by Farmers (Cents per Lb)[1]			U.S. Avg Price Paid by Farmers for Poultry Ration ($ per cwt)[1]			U.S. Cold Storage Holdings (Mil. Lb)[2]			Poults Hatched (Thousand Head)					
										All Breeds			Heavy Breeds		
Month	1966	1967	% Change	1966	1967	% Change	1966	1967	% Change	1966	1967	% Change	1966	1967	% Change
Jan	23.9	22.6	−5	3.47	3.73	+7	200	267	+34	5833	8415	+44	4731	7394	+56
Feb	24.0	21.4	−11	3.51	3.71	+6	182	275	+51	11,142	13,902	+25	10,194	12,895	+26
Mar	24.5	20.5	−16	3.49	3.72	+7	156	254	+63	21,228	22,462	+6	20,045	21,325	+6
Apr	24.4	19.1	−22	3.48	3.69	+6	122	207	+70	23,623	22,918	−3	22,110	21,896	−1
May	22.9	19.5	−15	3.52	3.67	+4	92	176	+91	24,604	23,554	−4	22,681	22,186	−2
Jun	23.0	20.1	−13	3.53	3.66	+4	69	149	+116	18,674	19,481	+4	16,531	17,540	+6
Jul	22.0	20.4	−7	3.66	3.62	−1	70	160	+129	10,431	10,823	+4	7836	8406	+7
Aug	21.8	20.6	−6	3.71	3.54	−5	104	220	+112	3462	4430[3]	+28	1548	2185[3]	+41
Sep	22.2			3.75			171			2100			711		
Oct	22.7			3.68			284			2428			1069		
Nov	23.8			3.68			397			2801			1556		
Dec	25.0			3.71			312			4623			3513		

[1]As of the 15th of the month.
[2]As of the first of the month.
[3]*Estimate based on eggs in incubators at beginning of month.*

TURKEYS RAISED

Year[1]	Light Breeds	Heavy Breeds	Total
	Thousand Head		
1965	11,959	92,781	104,740
1966	15,562	100,976	116,538
1967	15,429	110,199	125,628
1967 % change from 1966	−1%	+9%	+8%

[1]Includes poults hatched from September of preceding year through August of the year indicated.
Source. A.F.M.A. Poultry Survey Committee.

Ducks and Geese

DUCKS

Raising ducks is a specialized, large-scale operation or a side issue on general farms. Except for the Muscovy, all economic breeds of ducks originated from the Wild Mallard. The Runner, commonly called the Indian Runner, is an egg laying class and much smaller than breeds of the meat type. The Pekin duck is best for commercial farms where ducks are the principal source of income. Young ducks, forced for rapid growth and marketed at 8 to 11 weeks of age, are called "green" or "junior" ducks and weigh from 4½ to 6 lb each. The demand for ducks is not as general as for chickens and the demand for duck eggs is even more limited. Ducks lay a good-sized white egg, considerably larger than the chicken egg.

Location of Industry

Duck farming on a large scale has developed as a special business on Long Island and other places within easy shipping distances of large centers of population. Pekin ducks stand confinement well, are easily brooded, and less subject to disease than chickens. Artificial methods of hatching and rearing and labor saving machinery have been used very successfully.

Production

Breeding ducks lay 120 eggs during the hatching season from December to May. Twenty-eight days is the period of incubation of duck eggs other than the Muscovy which require from 33 to 35 days. On large duck farms hatching is done in incubators. Commercial pellets save labor and are used extensively for feeding ducks. They are fed in troughs or open hoppers, 4 times a day until the birds are 2 to 3 weeks old.

Ducks and geese are among the most rapidly growing and efficient producers of human food. Ducks attain a weight of 5½ to 6½ lb in 8 to 9 weeks. Ducks require up to ½ again as much feed to be reared and to produce eggs as do chickens. Growth to 4 weeks of age is improved by approximately 30% when pelleted rations are used instead of crumbled mashes. Starter rations for ducklings are made up in ⅛-in. pellets; for ducks over 2 weeks of age 3/16-in. pellets. Ducklings do not require water for swimming but they need clean water for drinking. They achieve maximum growth on rations varying widely in energy content. Rations containing 16% or more protein have produced normal growth with energy levels ranging from 950 to 1,350 Cal of metabolizable energy per pound of ration. With rations containing

16 to 18% protein, higher energy levels produce ducks with higher carcass fat content. As the energy content of the diet is increased over ranges from 800 to 1,250 Cal M.E. per lb of diet, efficiency of feed utilization is improved.

TABLE 35.1

GROWTH RATE AND FEED CONSUMPTION (PER 100 DUCKLINGS)

Age	Live Weight	Gain During Week	During Week	Total to Date	Per Lb Duckling to Date	Per Lb Gain During Week
Wk	Lb	Lb	Lb	Lb	Lb	Lb
At hatching	12	...	...	...	...	...
2	110	98	170	170	1.54	1.73
3	204	94	187	357	1.75	2.00
4	294	90	270	627	2.13	3.00
5	380	86	300	927	2.43	3.48
6	480	80	330	1257	2.60	4.12
7	525	65	335	1592	3.03	5.10
8	590	65	350	1942	3.29	5.38
9	646	56	340	2282	3.53	6.07
10	680	46	325	2607	3.83	7.00

Special Requirements of Ducks

Important factors in the feeding of ducks are age, feed conversion, fattening tendency, growth rate, and the form in which the feed is to be given. Practical rations for market ducklings require supplementation with niacin to prevent leg weakness. Addition of 10 mg niacin per pound of ration completely prevents leg weakness. Vitamin A is also required to the extent of 1,000 USP units per pound of ration. Beneficial effects from higher than minimal vitamin A levels in certain stress conditions warrant the use of generous safety margins. Practical rations without animal protein are not improved by a supplement of fishmeal, dried whey, fish solubles, fermentation solubles, or methionine. Broad or narrow spectrum antibiotics fail to cause any consistent improvement in growth or feed conversion.

GEESE

Goose raising has developed rapidly in recent years mainly for use in weeding cotton, sugar cane, strawberries, onions, garlic, and other crops commonly hoed. Even difficult Johnson and Bermuda grasses can be controlled. Concentration of geese in such areas makes processing and marketing possible. Geese are spring layers, starting about the middle of February. Peak production is reached by April and continues into May. High-

est production occurs in the 2nd or 3rd layer year, gradually lessening in succeeding years. Geese respond to light stimulation outside of the normal reproduction period. Commercial goslings grow so rapidly and in such concentration that pasture is hard to keep up. They are permitted to have clean, bare runs, and exercise on well drained sandy soil. Geese are largely herbivorous, once started can grow to maturity on grasses alone, if these are young and tender. Goslings can be reared in confinement, if fed a properly balanced diet, but they are much more easily managed and economically reared on pasture with grain added. Breeding geese relish pasture which greatly reduces carryover costs. Geese cannot be grown satisfactorily on dried-out or mature pasture.

Geese are reared on many farms in small numbers for their meat, feathers, and ability to weed crops. They are frequently on a scavenging program because they can live mainly on weeds, except for a finishing period. Goslings are available usually only in the spring of the year and the best market for geese is at Thanksgiving and Christmas. The soft, curved body feathers are a valuable by-product of market geese because they produce warm quilts and soft pillows. Geese forced to rely on weeds or pasture for nourishment are usually emaciated so it is desirable to have a special finishing period to give them a proper degree of finish for market.

Geese can be sold in the fall or processed in early life and sold as "green" or "junior" geese. Young geese are good gainers to the age of about eight weeks, showing a very fast growth rate, decidedly greater than other kinds of poultry. After this fast growth, a plateau is reached. Starting at about 20 weeks of age geese again begin gaining rapidly during the fattening period. Geese are produced in two ways—by relying completely upon forage for nutrients or feeding complete feeds. In the former case, gains are comparatively slow; with a complete feeding program, gains are extremely rapid. Geese go into a molt at 10 weeks of age and are not completely feathered out until 16 weeks of age. Geese weigh 7 lb at 6 weeks of age, using 2.25 lb of feed per pound of weight. At 9 weeks, geese weigh 9.9 lb, using 3 lb of feed per pound and are comparatively free of pin feathers. Geese receiving a low-energy feed do not grow as fast as those receiving high-energy feed. Goslings fed a high fat ration are heavy and show excellent efficiency of feed utilization.

The most frequent objection against geese for table use is the fatness of the bird but with "green" geese, overfattening is not a problem. From a nutrition standpoint, as stated, dietary addition of the vitamin niacin corrects a troublesome leg weakness problem. Good chick starter rations supplemented with niacin produce good gains in goslings. Riboflavin tends to be deficient in practical-type starter diets but other B-vitamins in corn-soybean meal type rations are adequate. Although the protein requirement

of goslings is 20%, 24% produces better feathers and growth. Breeding geese have been fed chicken breeder supplement plus free-choice of corn and oats for many years. Given a choice, breeder geese select 20 to 25% of a 27% protein mash, 30 to 35% of oats, and 35 to 60% corn.

Fattening Geese

Although geese are fast growing and mose efficient in feed conversion, practically free of disease, and excellent as a forager, they are poor reproducers. This is a deterrent to large-scale production. Goslings do not need feed until they are from 36 to 48 hr old. Green grass makes up most of their feed and only a very limited amount of grain is used. Fresh, clean drinking water should be supplied. After 2 or 3 weeks, if the goslings have plenty of young grass, they will usually not need any other feed. If the pasture is good, most goslings are raised from the time they are 2 to 3 weeks old to fattening without any additional feed. Whole grains are not fed until the goslings are well feathered. In a few areas young geese are fattened in large numbers by buyers who make this a specialty. Corn-on-the-cob and plenty of water are kept before the geese at all times and they eat the leaves of the cornstalks for roughage. Some farmers pen-fatten their geese in flocks of 20 to 25 and feed 3 times daily a moist, sloppy mash made of ⅓ shorts and ⅔ cornmeal. Some roughage or vegetables are also provided. An increase in weight from 4 to 6 lb can be obtained by this method of feeding.

Stuffing Geese with Noodles.—Another method which produces a much better fattened goose but involves considerably more work is to stuff geese with noodles for 3 to 4 weeks. From 8 to 10 geese are confined to a pen. The feeder holds a goose between his legs and stuffs it with noodles,

TABLE 35.2

AVERAGE WEIGHT OF YOUNG GEESE PER WEEK IN POUNDS

	Toulouse		Emden					
Week	Males and Females	Males	Males and Females	Males	Emden X Toulouse	Toulouse X Emden	African X Emden	All Crosses
0	0.25	0.26	0.25	0.25	0.23	0.23	0.24	0.24
1	0.65	0.69	0.49	0.49	0.41	0.43	0.43	0.43
2	1.4	1.4	1.5	1.6	1.4	1.4	1.4	1.4
3	2.9	2.8	2.9	3.0	2.7	2.6	2.6	2.6
4	3.8	4.0	3.7	3.7	3.5	3.7	3.7	3.6
5	5.2	5.5	4.8	4.9	4.7	4.9	4.9	4.8
6	6.5	7.0	6.1	6.3	6.1	6.3	6.4	6.3
7	7.6	8.1	7.2	7.6	7.3	7.2	7.8	7.5
8	8.3	8.9	8.1	8.5	8.1	7.9	8.5	8.2
9	8.4	9.1	8.4	8.7	8.5	7.9	8.8	8.5
10	8.7	9.3	8.6	9.0	9.1	7.8	9.1	8.9
11	...	9.8	...	9.6	...	...	...	...
12	...	10.1	...	10.1	...	...	...	...
13	...	11.3	...	11.2	...	...	...	...
14	...	10.9	...	10.8	...	...	...	...
15	...	11.5	...	11.6	...	...	...	...
16	...	11.5	...	11.9	...	...	...	...

TABLE 35.3

FEED CONVERSION PER WEEK FOR YOUNG GEESE
(MALES AND FEMALES)

Week	Toulouse	Emden	Crosses
0	...	...	...
1	1.18	1.40	1.44
2	1.62	1.35	1.48
3	2.19	1.70	1.75
4	2.76	2.04	2.06
5	2.65	2.19	2.08
6	2.57	2.18	2.05
7	2.62	2.06	1.90
8	2.78	1.99	1.91
9	3.12	2.19	2.02
10	3.75	2.74	2.77

TABLE 35.4

FEEDING PROGRAMS FOR GEESE[1]

	Starter Lb	Grower on Pasture Lb	Breeder Lb
Ground yellow corn	1014	1105	604
Oats, pulverized	100	100	100
Soybean oil meal, 44%, solvent	600	500	490
Meat and bone scrap, 50%	100	100	300
Fish solubles, condensed[2]	40	20	30
Alfalfa meal, dehydrated	50	...	150
Dried whey[3]	30	20	60
Bone meal, steamed	40	40	60
Limestone (calcium carbonate)	10	...	...
Salt, iodized	10	10	30
Manganese sulfate (65%)	0.50	0.50	1.0
Vitamin A (5000 IU/gm)	1.0	1.0	4.0
Vitamin D (1500 ICU/gm)	1.0	1.0	4.0
Vitamin mixture "2-4-9"[4]	1.0	1.0	2.0
Vitamin B_{12} (6 mg/lb)	1.0	1.0	2.0
Choline chloride (25% product)	1.0	...	...
Antibiotic supplement[5]	1.0	1.0	3.0
Niacin (grams of pure vitamin)	40 gm	...	...
Total, lb	2000.5	2000.5	2000.0
Calculated analysis:			
Crude protein, %	22.3	20.2	27.2
Crude fat, %	3.2	3.3	3.7
Crude fiber, %	4.0	3.0	5.0
Calcium, %	1.49	1.12	2.56
Phosphorus, %	0.88	0.78	1.43
Productive energy, calories per lb	860	210	725

[1]Prepared by P. L. Waibel. Minn. Poultry Dept. Publ. 5706.
[2]Fish solubles may be replaced with an equal amount of fishmeal.
[3]Dried whey may be replaced by dried skim milk, dried buttermilk, distillers' dried solubles, or dried yeast products.
[4]Vitamin mixture "2-4-9" refers to a mixture containing 2 gm riboflavin, 4 gm pantothenic acid, and 9 gm of niacin per pound. Commercial supplements with this vitamin potency are readily available.
[5]The antibiotic supplement should contain one of the following per pound of supplement: Penicillin, 4 gms; Aureomycin, 10 gms, Terramycin, 10 gms, or bacitracin, 10 gms.

Feeding directions:

1. Starting period (0-4 weeks). Use starter mash. Goslings may be placed on pasture, but feed no supplemental grain.
2. Growing period (after 4 weeks). With geese on good pasture, the grower mash should be fed in a free choice manner with whole corn and oats. With poor or no pasture, use starter mash in place of grower, and allow free choice with corn and oats.
3. Breeder geese: Feed breeder supplement in free choice manner with whole corn and oats.

TABLE 35.5

PRACTICAL FEED FORMULAS FOR DUCKS AND GEESE (1000 LB MIX)

	Duck Feeds (Pellet Form Only)				Goose Feeds (Pellet Form Only)		
% Protein	Starter 18%	Finisher 16%	Breeder Developer 18%	Breeder 18%	Starter 24%	Grower Finisher 16%	Breeder 18%
Time to Feed/Weeks	0-2	3-8	Feed as a Maintenance Ration After 9th Week	Start Feeding 4 wk Before Collecting Hatching Eggs	0-6	7-18	Start Feeding 4 wk Before Collecting Hatching Eggs
Ingredients	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*
Corn, yellow, medium grind	485	615	320	490	395	600	480
Alfalfa meal, dehyd. 17% protein	30	25	15	100	30	25	100
Soybean meal, solvent, 45% protein	145	170	. . .	130	320	160	140
Wheat middlings, standard	100	50	175	50	100	100	50
Oats or barley, ground	100	50	. . .	50	40	. . .	50
Corn distillers' dried solubles	40	. . .	. . .	25	20	. . .	25
Grain screenings	. . .	. . .	400	. . .	. . .	. . .	. . .
Molasses, cane	. . .	25	50	. . .	. . .	50	. . .
Meat & bone scraps 50% protein	20	20	15	20	20	20	20
Whey, dried	20	10	. . .	30	20	10	30
Fishmeal, 60% protein	25	. . .	5	40	25	5	40
Salt	[illegible]	5	5	5	5	5	5
Dicalcium phosphate	15	15	5	10	10	10	15
Limestone, ground	10	10	5	45	10	10	40
Vitamin-trace mineral premix	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5
TOTAL	1000	1000	1000	1000	1000	1000	1000

		DUCK				*GOOSE*		
Approximate Analysis		Starter	Finisher	Breeder Developer	Breeder	Starter	Grower Finisher	Breeder
Crude protein	%	18.0	16.1	13.4	18.1	24.2	16.3	18.4
Crude fat	%	3.4	3.1	4.2	3.2	2.8	3.1	3.2
Crude fiber	%	5.2	4.3	6.3	5.8	5.3	4.0	5.8
Productive energy	Cal per lb	872.0	919.0	592.0	829.0	784.0	907.0	818.0
Calcium	%	1.0	0.9	0.7	2.6	1.1	1.0	2.4
Phosphorus	%	0.9	0.7	0.6	0.7	0.8	0.7	0.8
Salt (added)	%	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Manganese (added)	mg per lb	28.0	28.0	28.0	28.0	28.0	28.0	28.0
Vitamin A	IU per lb	4985.	4680.	3216.	12,373.	4843.	4658.	12,350.
Vitamin D_3	ICU per lb	700.	700	700	500.	700.	700.	500.
Vitamin E	IU per lb	5.5	4.3	3.8	12.2	5.1	4.6	12.4
Vitamin B_{12}	mcg per lb	4.9	4.1	3.7	6.2	5.0	4.1	6.2
Riboflavin	mg per lb	2.9	2.5	2.0	3.1	2.9	2.5	3.1
Niacin	mg per lb	23.9	20.1	20.7	21.9	23.7	23.0	21.9
Pantothenic acid	mg per lb	7.1	6.6	5.3	7.3	7.5	7.2	7.3
Choline	mg per lb	667.0	551.0	377.0	605.0	784.0	552.0	613.0

beginning with 3 to 5 noodles 3 times daily and gradually increasing to 6 or 7 noodles 5 times daily. Noodles are made of scalded corn meal, ground oats, ground barley or wheat flour of about equal parts of each. A small amount of salt is added and the material is put through a sausage stuffer, cutting the product into pieces 3 in. long. They are boiled 10 to 15 min, dipped in cold water and then flour-dusted to keep them from sticking together. Just before they are fed, hot water is poured over them to make them slippery and to warm them. The noodles are put into the mouth one at a time and worked down by using the hands on the outside of the neck.

At the next feeding, if any feed can be felt in the crop, no noodles are given otherwise the birds will go off feed. Plenty of drinking water is kept before the geese. One man can feed from 50 to 100 geese by this method but it involves a lot of work. The first feeding is given at 5 A.M., and the last feeding at 11:00 P.M. "Noodling" will produce a gain of 6 to 10 lb.

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Game Birds

INTRODUCTION

State Commissions have raised game birds for many years. Pheasants, quail, chukars, partridge, wild turkeys, mallard ducks and geese are released by State game farms to public shooting areas. Recent farming practices have not been favorable to game birds. Intensive farming of large tracts with the use of machinery, the abandonment of poor lands and their reversion to solid stands of woods, and heavy pasturing of large acreages have contributed to reduced mixed cover necessary for high game population. Many private shooting preserves are maintained to furnish hunting on a year-round fee basis. Thousands of game birds are needed to fill the demand. Some states require game bird growers to be licensed. Pheasants are sold, ready-to-cook by supermarkets. Game birds can be mass produced in somewhat the same manner as turkeys. They grace many tables. Feed manufacturers sell game bird feeds although many game birds are fed turkey feeds. Pheasants comprise the largest market in most areas for game bird feeds but in the South there are large purchases of quail feeds. Frequently, the same feeds are fed to pheasants, quail, partridge, wild ducks, and geese.

Most feeds contain the following ranges of protein and energy: starter feeds 26–29% protein, growing feeds 16 to 19% protein, breeder feeds 18–20% protein, and metabolizable energy 1,250 and 1,350 Cal per lb. Rations for pheasants and quail developed at Cornell University are given in accompanying tables.

Upland game birds are only a few generations removed from the wild progenitors and are high-strung. There is a "peck" society in the yard and this caste system greatly complicates feeding procedures. Game birds in the wild are forced by natural conditions to balance their diet by eating weed seeds, insects, and vegetation during periods when grain is not available. They lack the ability to balance their own diets when given free choice. They have an utter horror of anything new and will starve for days before sampling a different type of feed.

QUAIL

The bobwhite quail is fast overtaking the pheasant as the most popular American game bird. Governmental agencies are helping to boost the development of the multimillion dollar shooting preserve industry in the

southeastern states. A favorable climate and availability of large tracts of relatively inexpensive land are factors in this development. Birds are weather-conditioned through exposure and flight-conditioned through exercise. Excellent quality from the shooting preserve standpoint is not always consistent with birds having the highest reproductive efficiency and size. Years ago, most preserves raised their own quail for releasing but the practice now is to buy grown, flight-trained birds and let someone else handle this side of the business.

Knowledge concerning nutrition of quail is incomplete but research is being carried on in Alabama, California and some other states. While data collected by wildlife experts are valuable, they do not apply for the most part to artificially reared birds in large groups.

Bobwhite quail are raised for the hunter, whereas Coturnix (Japanese) quail are raised primarily for research purposes. Many who raise bobwhite quail feed turkey starter crumbles to their stock. In the humid southeastern states it is essential to have good facilities for feed storage and not to store feed for longer than a month to prevent development of toxic fungi, such as *Aspergillus*. The range manager must know when and where to plant sorghum and other small grains to induce the released birds to stay. Pickled and smoked quail eggs, as well as dressed quail are products for luxury hotel trade. Coturnix quail is widely used as a source of human food in parts of the Orient and it has some potential for producing animal protein in underdeveloped countries. In Japan, the Coturnix quail is second only to domestic poultry. The Coturnix in the wild prefers diets relatively high in protein to thrive and reproduce efficiently.

FEEDS FOR PHEASANTS

The Ring-necked pheasant (*Phasianus colchicus*) has an extensive usage as a game bird in the United States. Methionine added to pheasant diets frequently causes an improvement. Studies from several State Experiment Stations have shown the need for approximately 28% protein in the usual corn-soybean meal diet for normal growth. The lysine requirement is 1.3% of a diet containing 20 to 24% protein. Addition of 0.1% methionine hydroxy analogue produces maximum growth and efficiency of feed utilization and causes a marked improvement in feathering. There is also an improved growth rate and egg production when the protein level is increased from 18 to 23% of the diet. Cannibalism is induced by reducing the arginine content from 6.9 to 3.9%. A linoleic deficiency inhibits egg production, but most practical diets contain ample amounts.

ANTIBIOTICS

Antibiotics have not been studied much in the diets of pheasants and quail. Their addition causes a significant improvement in hatchability, but

TABLE 36.1

RATIONS FOR PHEASANTS AND QUAIL

Typical rations	Pheasants			Quail			
	Starter	Grower	Breeder	Starter	Grower #1	Grower #2	Breeder
	Crumbles 0–4 Wk	1/8 In. Pellets to 9 Wk[1]	3/16 In. Pellets	Crumbles	Crumbles 4–9 Wk	1/8 In. Pellets 9–18 Wk	1/8 In. Pellets
	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton
Cornmeal, No. 2, yellow	790	850	900	945	865	875	900
Oats, heavy pulverized	...	...	200	...	...	200	200
Wheat standard middlings	...	200	100	...	200	300	100
Fat, stabilized	60	40	60	60	40	40	60
Soybean meal, 50% protein	850	700	250	700	700	400	250
Fishmeal, 65% protein	100	...	150	100	...	...	150
Fish solubles, dried	20	10	...	20	10	10	...
Brewers' dried yeast	25	...	50	25	...	...	50
Corn distillers' dried solubles	25	30	50	25	30	30	50
Whey product, dried	25	10	50	25	10	10	50
Alfalfa meal, dehydrated, 17% protein	60	80	50	60	80	80	50
Dicalcium phosphate	20	40	20	15	30	30	20
Calcium carbonate, ground	10	20	100	10	10	10	100
Salt, iodized	5	10	10	5	5	5	10
Premix[1]	10	10	10	10	10	10	10
Manganese sulfate, feed grade, lb	1	0.50	0.50	1	1	0.50	0.50
Zinc carbonate, lb	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Ethoxyquin, feed grade, lb	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Zinc bacitracin, gm	20	20	50	200	200	200	200
DL-methionine (or hydroxyanalog), lb	1.5	1	2	1.5	1	1	2
Stabilized vitamin A, USP units	20,000,000	8,000,000	8,000,000	20,000,000	8,000,000	5,000,000	18,000,000
D-activated animal sterol, IU	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Vitamin E supplement, IU	5,000	5,000	20,000	10,000	5,000	5,000	20,000
Choline chloride, gm	112	...	...	112	...	...	...
Riboflavin, gm	3	3	3	3	3	3	3
Nicotinic acid, pure, gm	40	40	...	40	40	40	...
Calcium pantothenate, pure, D-isomer, gm	6	5	10	6	5	5	15
Vitamin K (menadione sodium bisulfite), gm	2	2	2	2	2	2	4
Vitamin B_{12}, mg	6	6	6	6	6	6	6
Cornmeal to make total of ... (lb)	(10)	(10)	(10)	(10)	(10)	(10)	(10)

not in fertility during the declining phase of egg production. The pH of the intestinal tract of the *Coturnix* quail and domestic fowl are similar. Bile is either slightly acid or alkaline.

COTURNIX QUAIL

The nutritional requirements of *Coturnix* quail (*Coturnix coturnix japonica*) appear to be similar to those for bobwhite quail, except for the possible need for slightly superior quality diets at all ages. Studies of the Ring-necked pheasant and bobwhite quail also indicate similarity between the two species. Both require high protein diets for optimum early growth with a decreasing protein requirement as birds approach maturity.

Coturnix quail have a very short reproductive cycle. Only eight weeks are required to hatch an egg and raise a chick to sexual maturity. The *Coturnix* quail should not be confused with the bobwhite quail (*Colimus virginians*) or the California quail (*Laphortyx californica*). *Coturnix* quail are native to European and Asian countries and in some areas of Japan they have been raised for hundreds of years. *Coturnix* quail are extremely hardy birds and resist most common avian diseases. They mature at 6 weeks of age and are usually in full egg production by 50 days of age. Eggs are often obtained as early as the 35th day. Quail hens lay from 200 to 300 eggs per year. Fourteen hours of light per day are necessary to stimulate egg production. Adult female quail weights range from 110 to 160 gm; males are slightly smaller, weighing from 100 to 140 gm. Eggs hatch in 15 to 18 days depending on temperature, humidity, and genetic variability. Eggs should be turned mechanically every 2 to 4 hr, or turned by hand at least 3 times a day. When hatched, quail chicks are small, weighing about 6 gm and require careful attention. Provide heat for the first 3 or 4 weeks following hatching. Care must be exercised with small chicks to prevent drowning in water. Use petri dishes filled with pebbles at first. Water can be uncovered after chicks reach one week of age. Wood shavings, finely ground corn cobs, cane fiber, and peanut hulls are good litter materials. Use 2 to 4 in. on the floor and cover with paper. Adult quail produce extensively if they are allowed 12 sq in. of floor space per bird, ½ in. of feeder space per bird, and ¼ in. of trough space per bird. A ratio of 1 male to 5 females is optimal for breeding.

Quail chicks require a high protein ration. A 28% protein turkey starter has given excellent results during the first week. An all-mash ration is preferred to crumbles as chicks cannot eat the large crumbles at this age.

MINERAL REQUIREMENTS FOR PHEASANTS AND QUAIL

Grit and Minerals

There is a great deal of individuality with respect to grit consumption. Some birds eat hardly any; others become gluttons. The minimal calcium

requirement of hen pheasants is between 0.93 and 1.33% for the first 5 weeks, decreasing to 0.5% calcium for the 5- to 14-week period. A phosphorus level of 0.7% during the first 5 weeks and 0.38% for the 5- to 14-week period is satisfactory. Levels of 95 mg manganese and 62 mg zinc per kilogram are recommended for young Ring-necked pheasants. Increased amounts of vitamin D are needed when the diet contains a high proportion of phytin phosphorus. Vitamin D is unstable under certain conditions and its nutritional value is influenced by many dietary factors, such as ratios of calcium, phosphorus, and source of vitamin D. Thus, a generous margin of safety should be included in the diet.

The sodium requirements of both pheasants and quail are approximately 0.085% sodium, between 0.048 and 0.11% chlorine, and 0.3 ppm iodine of diet. The addition of 0.15% sodium chloride (salt) takes care of these requirements. If iodized salt is used containing 0.007% iodine, the iodine requirement of both pheasants and quail is satisfied. Good growth and livability of bobwhite to 16 weeks are obtained on a ration supplemented with 3,000 to 4,000 IU vitamin A per pound. It takes 6,000 IU vitamin A per pound before there is a reasonably high level of storage. Quail consume 3.26 lb of feed per bird to 16 weeks of age and require 11 units of feed to produce 1 unit of gain in weight. As stated, research at the University of Wisconsin shows that niacin is needed for pheasants raised in batteries. Brewers' or torula dried yeast are ingredients which will supply niacin. Battery-raised pheasants grow better than those reared in floor pens, even on the same ration. The faster growth in batteries puts a stress on their system and sometimes produces hock disorders. Dried yeast helps prevent such disorders at levels of about 5% which provides 25 mg of niacin per kilogram.

The addition of manganese and choline to the diet also helps cut down the incidence of slipped tendons, but does not entirely eliminate them. Cannibalism develops early in game birds and is probably the most serious problem of game breeders. Weak birds are quickly killed and a dead bird in a pen is stripped of feathers and flesh in a matter of minutes. An entire flock turns vulture when a bird is injured. Increasing the amount of salt in the diet is not effective; greens and raw meat scraps will not stop it. Game birds cannot be "raised just like chickens."

SQUABS AND PEAFOWL

A squab is a young pigeon which is marketed just before it is ready to leave the nest, usually at 25 to 30 days of age when it weighs from 12 to 24 oz. Pigeons are raised in all parts of the United States, but large squab producing plants have developed mainly in the northeastern and southeastern states and on the Pacific Coast. It is a hobby of some people since squab raising offers an opportunity for diversion and relaxation, as well as a means of supplying choice tender meat for home consumption.

Squab meat has a fine texture and delicious flavor, is tender and easily digested. A squab is of a desirable size for an individual serving. Feeding of pigeons differs radically from that of other poultry. Pigeons are not fed mash or green feed but have a diet of whole grains. They do not produce well on ordinary grain mixtures used for chickens as such feed is low in protein. From 13½ to 15% protein is necessary for optimum growth of squabs. High protein seed such as cowpeas, Canada peas, field peas, or garden wrinkled peas are used to get feed of the desired protein content. Pigeon feeds contain 13 to 15% protein, 60 to 70% carbohydrate, 2 to 5% fat, and not more than 5% fiber. Minerals are fed in a separate mixture. Pigeons do not utilize fiber to advantage. Salt, calcium, and phosphorus, in which grains are deficient, are supplied by special mineral mixtures. Drinking water is essential for good results.

A pigeon feed may be made up as follows: whole yellow corn 30, kafir or milo 25, cowpeas or field peas 20, wheat 20, hempseed 5. This feed contains 14.2% protein, 66.9% carbohydrates, 2.6% fiber, and 2.8% fat. Corn is one of the best feeds for pigeons, being the principal source of vitamin A. Both flint and yellow dent corn are used. Pigeons relish peas but they are relatively high in price.

Peanuts are sometimes used in place of peas but they do not keep as well and are usually higher priced. Raw soybeans are high in protein but are not desirable for pigeon feed. Given free choice, pigeons will eat more than 50% hempseed which is high in fat and sometimes added to the feed during the molting period. Vetch seed is low in fat but is high in protein. A small portion of other seeds and grains are used in pigeon feeds to add variety, e.g., millet, buckwheat, rice, and rape. Self-feeders are used or the grain is fed by hand twice a day. If breeders are over-fed they eat only their favorite grains and waste the other feeds.

It is essential to get squabs which grow rapidly. Birds are sometimes force-fed to get squabs which grow rapidly. After they are 10 to 12 days old, squabs are put in batteries and fed as follows: ordinary pigeon feeds are soaked in water for about 4 hr and the squabs given enough of the wet feed to fill their crops 2 or 3 times a day. A pair of high-producing pigeons eat about 105 lb of grain in a year. Smaller breeds consume about 90 lb and the large type about 125 lb. It takes 7 to 8 lb of feed to produce 1 lb of squab (dressed weight).

Peafowl Characteristics

Peafowl are ornamental birds, colored blue, white or green which originated in Northern India centuries ago. The male requires 3 yr to mature and is most gorgeous; its eyed (ocelli) saddle or train feathers range from 4 to 5 ft. The female matures in 2 yr and is graceful and dainty but somber colored. These birds are attractive in parks, zoos, and on estate lawns.

Their care, feeding, and management is similar to that given turkeys. Peafowl are fed small grains such as cracked corn, wheat, sorghum grain, corn, millet, as well as cottage cheese or crushed hardboiled eggs.

After 3 to 5 days of age give the pea chicks access to poult growing crumbles, green feed, grit, and fresh water. After 6 to 8 weeks of age, the chicks range with their parents and are good foragers picking up much of their feed requirements. Adults survive on water, whole grain, green feed, grit, oyster shell with pellets, and crumbles during the laying season. Mature hens weigh 7 to 9 lb and cocks 10 to 12 lb, and are a delicacy.

TABLE 36.2

PRACTICAL FEED FORMULAS FOR DUCKS AND GEESE (1000 LB MIX)

	Pheasant, Guinea, Partridge Feeds (Mash or Pellets)				Pigeon (Pellets Only)
% Protein	Starter 28%	Grower 22%	Finisher 16%	Breeder 17%	Parent Birds 16%
Time to Feed/Weeks	0–6	7–12	13 to Mkt.	Start Feeding 4 wk Before Collecting Hatching Eggs	Feed to Adult Breeding Birds
Ingredients	*Lb*	*Lb*	*Lb*	*Lb*	*Lb*
Corn, yellow, medium grind	390	570	755	640	455
Alfalfa meal, dehyd., 17% protein	30	25	20	50	50
Cowpeas or field peas	...	...	...	...	100
Soybean meal, solvent, 45% protein	425	290	170	130	100
Wheat middlings, standard	20	20	...	...	100
Oats or barley, ground	...	...	...	...	50
Corn distillers' dried solubles	20	15	...	20	20
Meat & bone scraps, 50% protein	50	25	25	25	20
Whey, dried	20	10	...	20	20
Fishmeal, 60% protein	25	20	...	50	20
Salt	5	5	5	5	5
Dicalcium phosphate	10	10	15	10	10
Limestone, ground	...	5	5	45	45
Vitamin-trace mineral premix	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5	2.5 or 5
TOTAL	1000	1000	1000	1000	1000

Approximate Analysis		Starter	Grower	Finisher	Breeder	Pigeon Pellets
Crude protein	%	28.6	22.4	16.3	17.5	16.4
Crude fat	%	2.6	2.9	3.2	3.4	3.1
Crude fiber	%	4.9	4.3	3.7	3.9	7.0
Productive energy	Cal per lb	787.0	894.0	994.0	919.0	748.0
Calcium	%	1.1	0.9	0.9	2.6	2.4
Phosphorus	%	1.0	0.8	0.7	0.8	0.7
Salt (added)	%	0.5	0.5	0.5	0.5	0.5
Manganese (added)	mg per lb	28.0	28.0	28.0	28.0	28.0
Vitamin A	IU per lb	4820.0	4583.0	4368.0	7585.0	7308.0
Vitamin D_3	ICU per lb	700.0	700.0	700.0	500.0	500.0
Vitamin E	IU per lb	4.4	4.2	3.5	8.0	8.3
Vitamin B_{12}	mcg per lb	5.8	4.8	4.1	5.9	4.9
Riboflavin	mg per lb	3.1	2.7	2.3	2.7	2.6
Niacin	mg per lb	21.7	21.0	19.1	20.2	21.9
Pantothenic acid	mg per lb	7.3	6.7	5.8	6.1	6.3
Choline	mg per lb	879.0	728.0	541.0	567.0	516.0

RATIONS FOR PHEASANTS AND QUAIL

Typical rations	Pheasants			Quail			
	Starter	Grower	Breeder	Starter	Grower #1	Grower #2	Breeder
	Crumbles 0–4 Wk	⅛ In. Pellets to 9 Wk[1]	3/16 In. Pellets	Crumbles	Crumbles 4–9 Wk	⅛ In. Pellets 9–18 Wk	⅛ In. Pellets
	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton	Lb per Ton
Cornmeal, No. 2, yellow	790	850	900	945	865	875	900
Oats, heavy pulverized	...	...	200	...	...	200	200
Wheat standard middlings	...	200	100	...	200	300	100
Fat, stabilized	60	40	60	60	40	40	60
Soybean meal, 50% protein	850	700	250	700	700	400	250
Fishmeal, 65% protein	100	...	150	100	...	...	150
Fish solubles, dried	20	10	...	20	10	10	...
Brewers' dried yeast	25	...	50	25	...	...	50
Corn distillers' dried solubles	25	30	50	25	30	30	50
Whey product, dried	25	10	50	25	10	10	50
Alfalfa meal, dehydrated, 17% protein	60	80	50	60	80	80	50
Dicalcium phosphate	20	40	20	15	30	30	20
Calcium carbonate, ground	10	20	100	10	10	10	100
Salt, iodized	5	10	10	5	5	5	10
Premix[1]	10	10	10	10	10	10	10
Manganese sulfate, feed grade, lb	1	0.50	0.50	1	1	0.50	0.50
Zinc carbonate, lb	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Ethoxyquin, feed grade, lb	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Zinc bacitracin, gm	20	20	50	200	200	200	200
DL-methionine (or hydroxyanalog), lb	1.5	1	2	1.5	1	1	2
Stabilized vitamin A, USP units	20,000,000	8,000,000	8,000,000	20,000,000	8,000,000	5,000,000	18,000,000
D-activated animal sterol, IU	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000	1,500,000
Vitamin E supplement, IU	5,000	5,000	20,000	10,000	5,000	5,000	20,000
Choline chloride, gm	112	...	...	112	...	...	...
Riboflavin, gm	3	3	3	3	3	3	3
Nicotinic acid, pure, gm	40	40	...	40	40	40	...
Calcium pantothenate, pure, D-isomer, gm	6	5	10	6	5	5	15
Vitamin K (menadione sodium bisulfite), gm	2	2	2	2	2	2	4
Vitamin B_{12}, mg	6	6	6	6	6	6	6
Cornmeal to make total of ... (lb)	(10)	(10)	(10)	(10)	(10)	(10)	(10)

Source: Distillers' Feed Research Council

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Feed Laws and Control

LABELING REQUIREMENTS

Government at all levels has become a dominating factor in the feed business. Originally, the States provided a measure of regulation and control. In the past decade, the U.S. Food and Drug Administration has overtaken the States in regulation. Now, local governments are taking direct action in the field of pollution. The Food and Drug Administration concerns itself principally with feed additive combinations, levels, and sanitation in handling food and feedstuffs. It is desirable to have available appropriate subsections of Title 21 Code of Federal Regulation and the Feed Additive Compendium. No mill is too small to be exempt from the Food and Drug Administration scrutiny. Common sense application of these regulations and the use of reasonable care and intelligence in the storage and handling of feed additives will create a more responsible industry.

The feed law along with the other concerned with poisons, remedies, fertilizers, and liming materials are enforced by the states. The law is basically a labeling law. There is no provision for questioning the efficacy of the feed. The State law is predicated on the idea that the feeder has freedom of choice and so long as he is provided with the necessary information on the label, it is up to him to read the label and make the choice in purchasing it. Although they are licenses, basically they are label laws. There is no question of value of the product. The feed law requires basic information on the label, stating the percentages of protein, fat, fiber, along with minerals. In the case of salt, there is a minimum and maximum guarantee. Vitamins are guaranteed when reference is made on the label. If a statement is made that this product is enriched with vitamins, a vitamin guarantee is necessary. Medication guarantees are also required. Control officials want to have necessary information on the label and superfluous information kept off. It is up to the educators to help consumers make wise decisions.

STATE LICENSING LAWS

Licensing is strictly a privilege to do business and can be revoked. But when an application for a license is made, the label is reviewed to be sure that necessary information is on it. Then, the license is issued. Officials like to clear up the label; it saves them a lot of trouble and in practically all cases it is done to their satisfaction. From then on, they are involved in quality control.

Minerals, vitamins, and medications are checked to be sure that the products on the market contain what they claim. Medications are in the feed for therapeutic purposes, growth promotion, or preventive purposes. If the efficacy of medications is questioned, the Federal Food and Drug Administration levels of feed additives are referred to. The Feed Additive Compendium is used in reviewing labels to be sure that the levels of medication that are being represented as in the feed have been recognized for the value and purposes for which they are in there—prevention of coccidiosis, growth promotion, and feed efficiency. Another publication used by the feed control officials is the official Feed Control Officials publication which contains definitions of standard ingredients used in the manufacture of feeds. Officials are bound by law to the terminology used by this association for a specific feed ingredient.

Here is one example. There are several different kinds of alfalfa. If the label uses the term "sun-cured" alfalfa, this means the aerial portion of the alfalfa plant which is reasonably free of other crop plants or weeds and molds has been sun cured and finely ground. If it is chopped instead of finely ground, it must be designated as chopped alfalfa or chopped alfalfa hay. On some classes of alfalfa, there are protein and fiber limitations. Alfalfa leaf meal is defined as leaves that are separated from the alfalfa plant, dried and finely ground. It must contain not less than 20% crude protein and not more than 18% crude fiber.

Each and every ingredient in the feed must be on the label and they must be named in descending order of their amount in the feed. Percentages are no longer required. Ingredient terms are universal throughout the United States. Feed production committee of the American Feed Manufacturers Association is promoting uniform feed laws for all states. Some states use the same approach as the Federal Food and Drug Administration. In other words, try to prevent violations from occurring. Other states use "random sampling." They sample 5,000 to 8,000 samples of feed and base their enforcement upon the analytical results of the samples they have drawn. This is quite expensive. Other means are "selective sampling." In other words, only samples are taken when it is believed that they are in violation of the law. Some do this by a system of mill inspections and examination of feedstuffs, mixing procedures, and labels without drawing samples.

Suppose a label called for a coccidiostat in the feed but it had none. About all that is necessary to correct the situation is to ask the feed manufacturer how many chickens are being fed and how many farms were using his feed. Then, ask who would have to pay for the losses if coccidiosis got into their flocks with heavy losses and the feeders found out that he did not have a coccidiostat in his feed. His reaction would be to get that matter taken care of right away. This system of enforcement

takes a relatively short time to get most of the feedmen aware of the label. The law contains the provision whereby control officials have the authority to inspect records.

Product names cannot be misleading. A growing mash cannot be termed a laying mash or vice versa. Misbranding is considered a violation. Suppose vitamin D_2 was put in a feed for chickens instead of D_3, the source of vitamins, either animal sterol or plant sterol, has to be declared.

Control laboratories analyze feed samples and the results are used to enforce the law. The law states that if a State standard does not exist, any prevailing feed standard such as a Federal standard can be used for enforcing the law.

UNITED STATES FOOD AND DRUG REGULATIONS

In 1895, Connecticut passed a law containing provisions for regulation of food sales for man and animals. Massachusetts passed the first feed law in 1896. By 1920, 38 States had some form of regulation in effect. Today, all States except Nevada have laws regulating the sale of feeds. Justification for such laws is the inability of buyer to judge the quality of ground ingredients, by-products, or mixtures by visual inspection. The buyer needs assistance in determining value, and protection from those who sell material of poor or varying quality. The fact that laws were passed to control the sale of ingredients and formula feeds implies that everything was not always on the "up and up." State and Federal government publications continue to advise the farmer to beware of feeds containing low-grade ingredients.

The U.S. Food and Drug Act was passed in 1906 to control feeds shipped in interstate commerce. In 1938, the Food, Drug and Cosmetic Act added certain requirements for labeling of feeds. An additive amendment restricted the use of estrogenic compounds and arsenicals that were not proven safe. Considerable confusion arose regarding compliance procedures. For the first time, manufacture of feeds was brought under Federal Government scrutiny. Inspection of feed plants and methods for storing and handling additives were suggested to feed manufacturers. Better housekeeping and production methods had to be followed to comply. Design, engineering and layout of new feed mills have also been influenced by passage of the Delaney Amendment.

There is a word of warning from the Food and Drug Administration on feeds prescribed by veterinarians. Where new drug substances are involved, they cannot be used legally even on the prescription of a veterinarian unless the prescription is the subject of a new drug application. Old drugs cannot be mixed either unless they comply. Feedmen should be cautious

about mixing anything for a farmer unless he knows what it is, otherwise he is increasing his liability.

THE ASSOCIATION OF AMERICAN FEED CONTROL OFFICIALS

The Association of American Feed Control Officials (AFCO) was organized in 1938 and adopted uniform standards of feed analysis. In 1937, AFCO collaborated with AFMA in preparing a model feed law. Uniform laws throughout all states would make the manufacture and marketing of feed much easier for firms selling in two or more states. Through the joint efforts of industry and state control officials, farmers have been provided with product information. Uniform feed laws and tonnage reporting systems would move the feed industry forward on the road to progress.

Is a poultryman who mixes his own feed a "feed manufacturer"? More than half of the feed in the United States is manufactured by someone other than a feed manufacturer. Should the farmer abide by control laws written to protect the farmer as a buyer of feed? The so-called feed industry is basically a part of the framework of agriculture and food economics. Agriculture has already changed tremendously in recent years. Most of the things that were said would happen are already realities. Farming as a mode of living has passed. Poultry production is a matter of converting crops into human foods; it is food production. Poultry feed is not formulated and manufactured for consumers but for producers of meat and eggs for consumers. The feed industry is a part of agriculture and will shift as agriculture changes its course in the future. Business, government, and consumers are teammates in the production of food.

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Economics

FARM MIXING OF FEED

Poultrymen sometimes wonder if it is advantageous to mix feeds from the ground up at the farm. Hiring feed manufacturers to do the work costs money and it would appear that savings could be achieved if it were done on the farm. Certainly, farm mixing is attractive when no consideration is given to the labor involved. A number of factors, however, should be taken into consideration. Does the feed volume justify the investment in equipment and its cost of operation? Can the feeder be sure of getting quality feed ingredients? Feed manufacturers hire trained personnel to check the quality of ingredients that go into their feeds. Will the feeder provide the nutritional and other customer services that are available through feed manufacturers? Can the feeder buy ingredients in large enough quantities to purchase advantageously, as feed manufacturers do. Can feeders realize a return on their investment in processing and storage equipment? Can feeders finance operations if needed?

When feeders answer these questions to their own satisfaction, they are in a better position to know whether it is more advantageous to spend their time managing their poultry operations or competing with feed manufacturers in mixing feed. In most instances, they can make more money by concentration on the job they know best—the poultry operation.

Ingredient cost is only 1 of 10 items that appear in every ton of formula feed purchased. These items are: (1) ingredient cost; (2) grinding, mixing, and processing; (3) risk and credit; (4) investment and operating costs; (5) research and feeding trials; (6) cost of maintaining a place of business; (7) transportation; (8) shrinkage and loss; (9) service; and (10) business incentive or profit.

When the farmer assumes 1 or more of these 10 cost items, there should be lower out-of-pocket costs. If the feeder is now paying the price of a good commercial feed, he should get satisfactory and competent service because he is paying for it.

The formula feed industry produces feeds for various classes of poultry and livestock. It is the hub of the food industry because feed comes before food. It is a service industry which mixes feedstuffs to satisfy the nutrient requirements of the various animals. The reason for the industry's existence is that it outperforms mixing of feeds by farmers. The feed industry has grown tremendously over the years, primarily on the basis of making feeds profitable for feeders. Formula feeds are a conversion prod-

uct and not an end product. They are unique because they are not only necessary products sold to the feeder but they also provide a market for the farmers' grains along with by-products of various industries.

A breakdown of the wholesale prices of commercial formula feeds show that manufacturing accounts for 6 to 10% of total feed costs, raw materials 65 to 75%, and freight 10 to 20%. Greater emphasis is being placed on capacity operation since fixed costs in relation to tonnage are less.

ECONOMICS OF BROILER PRODUCTION

Broiler production is one of the most efficient enterprises in agriculture. Despite an enviable record there are still areas where further improvements can be made. Because of the uncertainty of leukosis and other losses in raising pullets, many producers house 25% fewer birds than their operations require. Let us assume that the number of breeder hens required is 26,000 ready-to-lay at 26 weeks, but because of unexpected losses only 20,000 birds are housed. In addition to the obvious problem of insufficient eggs to meet grow-out operations other costs continue. Floor space, nests, litter, lights, and other fixed costs are not very different whether 20,000 to 26,000 birds occupy the house. Some producers start extra chicks intended as breeders, should excess mortality occur. They sell the excess off as meat birds if the flock lives well. Having reserve breeders permits selecting more critically at housing and insuring that only eggs of known quality are set.

Let us assume a total cost of 60c per dozen as a reasonable figure to produce hatching eggs for a broiler operation. This is based on an average of 10 doz eggs of hatching quality from each hen in a 28- to 32-week period. It costs 9.25c for each 1-day-old chick put down. Following are results for broilers raised on three energy levels in starter growing and finishing mashes.

TABLE 38.1

COST PER POUND OF LIVE BROILER TO PROCESSOR BASED ON DIFFERENT NUTRIENT DENSITIES

	High Plane	Medium-High Plane	Medium Plane
Hatched chick @ 9¼¢	2.37¢	2.50¢	2.64¢
Feed cost @ $70 per ton	7.35	7.87	8.40
Labor for growout—est.	1.50	1.50	1.50
Deliver to proc.—est.	.50	.50	.50
Cost per pound to processor	11.72¢	12.37¢	13.04¢

Producers take precautions to retain as far as possible allowable moisture in the dressed pack. Per pound cost is substantially affected by dressing percentages, as shown in Table 38.2.

TABLE 38.2

EFFECT OF DRESSING PERCENT ON COST ON SEVERAL PLANES OF NUTRITION

Nutrient Density	Cost per Lb Live Bird	Dressing %		
		70	75	80
High plane	11.72¢	16.74¢	15.68¢	14.65¢
Medium-high plane	12.37	17.67	16.49	15.46
Medium plane	13.04	18.63	17.39	16.30

TABLE 38.3

BROILER OPERATION

Breeder Hen

Chick Startena	4.8 lb × 18.0% =	0.864
Developer	16.1 lb × 13.0% =	2.093
	5.9 lb × 13.0% =	0.767
Layena	90.0 lb × 16.0% =	14.400
		18.124

Production

Egg production (9 months lay) 144 eggs
144 eggs × 88% hatching eggs = 126 eggs
126 hatching eggs × 76.5% hatch = 96 chicks
96 chicks × 96% livability = 92 live chicks

Recovery

18 eggs × 21 oz = 3.78 lb × 88% edible = 3.32 lb × 12.9% protein = 0.43
7.5 lb hen × 88% livability = 6.6 lb
6.6 lb
0.9 cockerels per hen

7.5 lb × 49% edible[1] = 3.67 lb × 20% protein = 0.73

1.16

1.16 + 18.124 = 6.40% recovery

Broiler Starter	2.60 lb × 23.0% =	0.598
Broiler Finisher I	3.90 lb × 20.0% =	0.780
Broiler Finisher II	1.70 lb × 18.0% =	0.306
		1.684

Recovery

Broiler 3.56 lb × 48.4% = 1.72 lb edible meat
1.72 lb × 18.6%[2] protein = 0.320 lb

% recovery—19%

Total Recovery for Total Broiler Operation

	Lb Protein Fed	Lb Protein Recovered
1 Breeder Hen	18.124	1.16
92 Broilers	154.928	29.44
	173.052	30.60

% recovery—17.7%

[1]Source: Vermont's Poultry Pointers 10/10/53
[2]Source: Agr. Yearbook 8, Agr. Res. Serv., U.S. Dept. Agr. Table 1

TABLE 38.4

POULTRY PRODUCTION IN THE UNITED STATES[1] (1967)

Area	Chickens	Eggs	Broilers	Turkeys
Eastern	88,201,609	966,977	373,970	14,032
Central	160,610,208	1,472,644	184,928	41,476
Southeast	71,366,343	577,816	788,905	5,579
Pacific	49,688,515	620,766	71,944	19,309
Total United States	369,866,675	3,618,203	1,419,747	80,396

[1]By areas.

TABLE 38.5

AVERAGE AMOUNT OF FEED REQUIRED TO PRODUCE 1 LB OF THE DIFFERENT KINDS OF MEAT AND NUMBER OF PRODUCTION UNITS REQUIRED TO PRODUCE 1,000 LB OF EACH MEAT (1953)

Meat Production Unit	Avg. Net Gain in Weight Lb	Avg. Time Required to Make Gain Weeks	Number Production Units Required to Produce 1,000 Lb Meat	Avg. Amount Feed Required per Lb of Meat Produced (Lb)
Beef (fattening yearlings from 650 to 900 lb)	250	48–52	4 steers	4.0 feed and 7.0 roughage
Lamb (fattening from 60 to 90 lb)	30	13–14	34 lambs	4.0 feed and 4.0 roughage
Hogs	200	24–26	5 pigs	3.7 feed
Turkeys (mature)	19.2	24–26	52 turkeys	3.9 feed
Turkeys (broilers)	8.2	12–14	122 turkeys	2.6 feed
Chickens (broilers)	3.2	9–11	308 chickens	2.4 feed

TABLE 38.6

EXPECTED FEED PER DAY AND PER DOZEN EGGS BY 100 HENS OF DIFFERENT WEIGHTS AND EGG PRODUCTION (POUNDS)

	Feed Consumed by[1]					
	4-Lb Hens		5-Lb Hens		6-Lb Hens	
Eggs per 100 Hens per Day	Per Day	Per Doz Eggs	Per Day	Per Doz Eggs	Per Day	Per Doz Eggs
0	15.8	—	18.6	—	21.2	—
10	16.7	20.1	19.6	23.6	22.1	26.6
20	17.6	10.5	20.4	12.2	22.9	13.7
30	18.4	27.4	21.3	28.5	23.9	9.6
40	19.3	5.8	22.2	6.7	24.7	7.4
50	20.2	4.8	23.1	5.5	25.6	6.1
60	21.1	4.2	24.0	4.8	26.5	5.3
70	22.0	3.8	24.9	4.3	27.5	4.7
80	22.9	3.4	25.8	3.9	28.1	4.2
90	23.8	3.2	26.7	3.6	29.2	3.9
100	24.7	3.0	27.6	3.3	30.1	3.6

[1]Feed assumed to contain 1,350 cal of metabolizable energy per pound diet.

TABLE 38.7

FEED UNITS REQUIRED PER UNIT OF EGGS AND POULTRY PRODUCED, SELECTED YEARS, 1940-66[1]

Year Beginning Oct. 1	Per Doz Eggs	Per Lb of Liveweight	
		Turkey	Broiler
	Feed Units	Feed Units	Feed Units
1940	7.3	7.2	4.9
1945	7.8	6.3	4.6
1950	7.2	5.6	3.7
1955	6.7	5.2	3.3
1960	6.4	5.4	2.9
1965	6.5	5.2	3.0
1966	6.6	5.3	3.0

[1]Feed units used per dozen eggs or per pound of liveweight turkey or broiler produced. A feed unit is the nutritive equivalent of 1 lb of corn.

Fixed costs include 5¢ per lb for processing, 0.8¢ per lb freight, and 0.7¢ per lb for administrative costs for a total fixed cost of 6.5¢ per lb. The time between the watering and slaughtering has a pronounced effect on degree of dehydration, particularly during hot weather when birds are confined in crates on the truck.

One hundred Leghorn hens require 19 lb of feed per day for maintenance. For every 10 eggs they lay approximately 1 extra pound of feed is required. Therefore, the higher production obtained, the less feed is required per dozen of eggs.

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TABLE 38.8

POULTRY AND EGG PRODUCTION AND U.S. POPULATION, 1957–1967

Year	Production: Broilers, Quantity	Broilers, As a Percentage of 1957–59	Turkeys, Quantity	Turkeys, As a Percentage of 1957–59	Eggs, Number	Eggs, As a Percentage of 1957–59	U.S. Population Including Armed Forces Overseas, Number	U.S. Population, As a Percentage of 1957–59
	Million Lb	%	Million Lb	%	Millions	%	Millions	%
1957	4,683	88	1,356	98	61,026	98	171.3	98
1962	6,907	131	1,626	118	63,569	103	186.7	107
1967	9,338	176	2,265	164	69,588	112	199.1	114

TABLE 38.9

PER CAPITA CONSUMPTION OF POULTRY MEAT AND EGGS, 1954–67

Year	Chicken: Broilers	Chicken: Other	Chicken: Total	Turkey	Total Poultry	Eggs: Shell	Eggs: Processed	Eggs: Total
	Lbs	Lbs	Lbs	Lbs	Lbs	Number	Number	Number
1954	13.7	9.1	22.8	5.3	28.1	351	25	376
1957	19.1	6.4	24.5	5.9	31.4	335	27	362
1960	23.4	4.6	28.1	6.1	34.1	306	28	334
1964	27.5	3.5	31.0	7.3	38.3	287	31	318
1967	33.4	4.1	37.5	8.8	46.3	292	31	323

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Appendix

PART I—GLOSSARY

Absorption Absorption pertains to the uptake of nutrients, water, or other substances by stomach or intestinal walls following digestion of food. For example, glucose, a simple sugar, is absorbed without change, but starches must be broken down into sugars before absorption can take place. In food processing, absorption may also refer to uptake of other substances by foods, such as absorption of fats by foods during cooking in deep fat, or absorption of water by cereals during cooking.

Adipose Adipose is commonly used in describing the part of the body where fat is stored, which is adipose tissue.

Adrenal The adrenal glands are ductless glands near the upper end of the kidneys. Their secretions are essential for the maintenance of life

Amino acid Organic compound of carbon, hydrogen, oxygen, and nitrogen. Each amino acid molecule contains one or more amino groups ($-NH_2$) and at least one carboxyl group ($-COOH$). In addition, some amino acids (cystine and methionine) contain sulfur. Many amino acids linked together in some definite pattern form a molecule of protein.

Antibiotics Chemical substances, "against life," which are produced by certain living cells, such as bacteria, yeasts, and molds that are antagonistic or damaging to other living cells, such as disease-producing bacteria. Antibiotics may kill living cells or prevent them from growing and multiplying. Penicillin is an example of an antibiotic that inhibits or destroys certain bacteria that cause disease in man.

Antibody Specific substances produced in the body to react against disease-producing or other foreign materials in the blood stream. Some antibodies remain in the blood stream for many years and help to give a person immunity to certain diseases.

Antioxidant A substance capable of chemically protecting other substances against oxidation.

Ascorbic acid The chemical name for vitamin C.

Available A nutrient is available to the body when it is in the form that can be absorbed from the digestive tract and then used for its intended function in the body.

Avidin A protein material that can combine with biotin, causing the vitamin to be unavailable to the body Cooking renders avidin inactive.

Bacteria Very small, one-celled organisms visible only under a microscope and widely distributed in the air, water, soil, and animal and plant tissues They have some useful functions, such as in decaying dead matter and in fermentation of fruit or vegetable juices—as in the making of sauerkraut. Many bacteria produce disease or cause harmful spoilage of foods.

Basal metabolism The energy produced by an individual during physical, digestive, and emotional rest, measured directly by the heat evolved and indirectly by the oxygen consumed and carbon dioxide given off.

Bile A thick green or yellow fluid formed in the liver, collected in the gallbladder, and emptied into the intestinal tract at intervals, particularly during the digestion of fats. It is a complex mixture containing salts of bile acids, which aid in digestion of fats, and cholesterol and other substances from different body sources. It carries cholesterol from the liver into the intestine for excretion or for reuse in digestion as needed.

Biochemistry The chemistry of living things, plant, and animal.

Biological Pertaining to the science of life.

Biological value The biological value of a food protein is the efficiency with which that protein furnishes the proper proportions and amounts of the amino acids needed, at the time of synthesis of body proteins, by man or animals eating these foods. The more nearly a protein supplies the tissues with the necessary proportions and amounts of these amino acids, the higher is its biological value.

Biosynthesis The coming together of chemical building units to form new materials in the living plant or animal.

Biotin One of the ten recognized vitamins of the B complex. It is widely distributed in

foods. It is needed in the diet of certain laboratory animals, such as the chick, rat, and mouse. A deficiency in man has never been observed under usual conditions.

Bran The outer coarse coat of grains.

Calcification Process by which organic tissue becomes hardened by a deposit of calcium salts.

Caloric Pertaining to heat or energy; used in reference to the caloric value of a food, it means the heat or energy that can be obtained as muscular work and heat when the body uses or metabolizes that food.

Calorie The unit by which heat is measured. It is defined in terms of the amount of heat required to raise the temperature of a specified amount of water 1°C. A small calorie (written with a small c) is the amount of heat required to raise one gram of water from 14.5° to 15.5°C. A large Calorie (capital C) is the amount of heat required to raise 1,000 gm (1 kg) of water from 14.5° to 15.5°C. The large Calorie is used exclusively in expressing the caloric value of foods and the caloric needs of humans and animals. (Calorie and caloric, as adjectives, usually are not capitalized.)

Calorimeter An instrument for measuring the heat change and the energy in any system.

Carbohydrate An important group of organic substances that contain carbon, hydrogen, and oxygen. The hydrogen and oxygen are present in the same proportion as in water (H_2O), and there is one molecule of water for every carbon. Starch and sugar are carbohydrates.

Carcass The part of an animal's body that is used for meat. After an animal is slaughtered and the entrails, head, feet, and lower parts of legs and hide are removed, the carcass remains. It is hung and chilled and later is cut up into steaks, roasts, etc.

Carotene A yellow compound of carbon and hydrogen that occurs in plants and is a form of vitamin A. Alpha, beta, and gamma carotenes may be converted into vitamin A in the body.

Cartilage A special form of white connective tissue that is attached to the ends of bones that are either divided into joints or united by joints. It is more flexible but not so strong as bone. Cartilage is the first substance to form in growing bone; then calcium and phosphorus are deposited in the cartilage, thus changing it to bone.

Catalyst A substance that speeds up the rate of a chemical reaction but is not itself used up in the reaction.

Centigrade (C) A thermometer scale in which water freezes at 0°C and boils at 100°C. To change to degrees Fahrenheit, multiply degrees centigrade by 9/5 and add 32. Also CELSIUS (C.), the preferred form approved by the Ninth General Conference on Weights and Measures in 1948.

Chemical additives Substances added to foods to improve their flavor, color, texture, or keeping quality.

Chlorophyll The green coloring matter present in growing plants, which under stimulus of light is active in the manufacture of carbohydrates from carbon dioxide and water.

Cholesterol The most common member of the group of sterols; it is present in many foods and also can be made within the body.

Coagulation The change from a fluid state to a thickened jelly, curd, or clot.

Collagen A protein that forms the chief constituent of the connective tissue, cartilage, tendon, bone, and skin. Collagen is changed to gelatin by the action of water and heat.

Conduction The transmission of heat or electricity through an object, or from one object to another in direct contact with it, without the motion of the conducting bodies. Conduction is different from convection, which is the transmission of heated particles, and different from radiation, which is the transmission of heat effected through the atmosphere.

Decalcification The withdrawal of calcium from the bones where it has been deposited. It may be caused by an inadequate supply of calcium in the diet so that calcium has to be taken from the bones to help meet the body's needs. It may be caused also by an imbalance in some of the hormone activity in the body.

Deficiency disease A disease resulting from an inadequate dietary intake of something required nutritionally; most commonly refers to diseases resulting from dietary deficiencies of vitamins or trace elements.

Dehydrated foods Products from which most of the water has been removed in order to improve their stability during storage.

Dietetics The application of the science of nutrition to the feeding of individuals and groups of people.

Digestion In physiology, the breaking down of foods into simpler components in the alimentary or digestive tract. Foods may be digested by natural body enzymes in the

stomach and intestines, or be broken down similarly by the chemist using chemicals and prepared enzymes, heat or microorganisms. Proteins are digested to peptides and amino acids, fats to fatty acids and glycerol, carbohydrates to dextrins and sugars. Buttermilk is an example of a food partially digested by natural enzymes and microorganisms in the milk.

Edema Swelling of a part or the entire body due to the presence of an excess of water. Edema is most noticeable at the end of the day around the ankles, which increase in size. When the condition becomes severe, an impression remains for a few minutes where a finger was pressed against the skin.

Emulsify To make into an emulsion. When small drops of one liquid are finely dispersed (distributed) in another liquid, an emulsion is formed The drops may be held in suspension by an emulsifying agent, which surrounds each drop and makes a coating around it.

Endocrine Secreting internally, or into the blood stream, as endocrine glands, or glands of internal secretion.

Endosperm The starchy portion within the kernel of wheat, corn, or other cereal, from which refined flour is produced after the germ and fibrous outer layers are removed

Energy Capacity to perform work.

Enzymatic Related to that class of complex organic substances called enzymes, such as amylase and pepsin, that accelerate (catalyze) specific chemical reactions in plants and animals, as in digestion of foods.

Enzyme One of a class of substances formed in living cells It speeds up chemical reactions but is not changed during the process

Epidemic A disease is epidemic when many people in a region are attacked at the same time or when the disease is spreading rapidly

Epithelial Refers to those cells that form the outer layer of the skin, those that line all the portions of the body that have contact with the external air (such as the eyes, ears, nose, throat, and lungs), and those that are specialized for secretion as the liver, kidneys, and urinary and reproductive tracts

Evisceration Of poultry and fish, refers to removal of the intestinal tract and other organs from the carcasses

Excretion The products of digestion and metabolism that are discharged from the body —feces from the intestinal tract and urine from the kidneys

Factor In nutrition, any chemical substance found in foods. A factor might be a vitamin, mineral, or any other nutrient or nonnutrient Usually it has some effect on growth or reproduction of animals A factor may be "identified" or remain "unidentified." In arithmetic, factor is a value or ratio expressing the relationship between two items, such as liters of oxygen and the equivalent amount of oxygen in grams

Fahrenheit(F) A thermometer scale that marks the freezing point of water at 32°F and the boiling point at 212°F.

Fat A glyceryl ester of fatty acids. Fats generally are substances of plant and animal origin. Fat may be in solid form, as butter, margarine, lard, or other shortening, or in liquid form, as the vegetable oils

Fat-soluble Refers generally to substances that cannot be dissolved in water but can be dissolved in fats and oils, or in fat solvents. The fat-soluble vitamins are vitamins A, D, E, and K

Fatty acid Organic compound of carbon, hydrogen and oxygen with carboxyl group which combines with glycerol to make a fat

Fermentation The chemical changes brought about by the activity of enzyme systems of microorganisms. For example, yeast contains enzymes that produce carbon dioxide and alcohol from sugar. In breadmaking, it is carbon dioxide that causes the dough to rise. The souring of milk is lactic fermentation, some of the milk sugar being converted by the action of lactic acid bacteria into lactic acid. Lactic fermentation also is utilized in making pickles.

Fortify To add one or more nutrients to a food so that it contains more of the nutrients than was originally present before processing Milk often is fortified with vitamin D.

Fractionation A term used by the chemist when he takes natural materials apart in the laboratory by physical means He does this for various reasons—usually to isolate or purify some specific compound present in feeds or foods.

Gastric Pertaining to the stomach.

Gene The particle in the cell that carries hereditary characteristics. Genes control the development of the body and its specific functions

Genetic Pertaining to heredity.

Germ The part of a cereal seed that grows and produces new plants.
Gestation Pregnancy.
Glandular Adjective of gland. A gland is an organ that makes and discharges a chemical substance that is used elsewhere in the body or eliminated.
Gluten An elastic substance that gives adhesiveness to dough. It is formed when the proteins in flour, especially those in wheat flour, absorb water. Gluten assists in giving shape to the cooked product as it coagulates when heated.
Gonadotropins Hormones from embryonic sex glands.
Growth-regulating substances Chemicals that in extremely small amounts will affect the rate or type of growth of cells, tissues, and organs and sometimes referred to as hormone-like substances.
Hard (water) Water containing soluble salts of calcium and magnesium and sometimes iron. Hardness caused by bicarbonate salts of these metals is known as temporary hardness, because boiling expels the carbon dioxide and converts the bicarbonate to the insoluble carbonate, forming incrustation on the walls and bottom of the container. Hardness from chlorides and sulfates of calcium and magnesium is not affected by boiling.
Heat-labile Changeable by heat; unstable to heat.
Hemicellulose A complex carbohydrate that occurs widely in plants as a structural part of their cell walls. It differs chemically from cellulose by being subject to hydrolysis with dilute mineral acids.
Hemoglobin A protein in the blood that contains iron and carries oxygen from the lungs to the tissues.
Hemolytic Refers to the destruction or breakdown of the red blood cells.
Hemorrhage Loss of blood.
Homogenized A liquid of two or more components broken up into small droplets of the same size. Homogenized milk has been treated mechanically to break the fat into such small globules that it will not rise to the top as cream.
Hormone A chemical substance that is produced in an organ called an endocrine gland and is transported by the blood or other body fluids to other cells. A hormone greatly influences the functions of some specific organ and of the body as a whole. Thyroxin is a hormone secreted by the thyroid gland, and insulin is a hormone secreted by the pancreas.
Hyper A prefix meaning above, beyond, in excess of the normal or average.
Hypertension An abnormally high blood pressure.
Hyperthyroidism Overactivity of the thyroid gland so that it secretes abnormal amounts of the hormone thyroxin.
Hypertrophied Increase in the size of an organ, independent of natural growth.
Hypervitaminosis The undesirable effects produced by taking an excess of a vitamin concentrate or pure vitamin.
Hypo A prefix denoting a deficiency or lack or less than the normal or desirable amount.
Inactivate To suspend or terminate certain biological activities, such as by heat, irradiation, or other forms of energy.
Inedible A substance that is not fit for food, such as poisonous nuts and plants. Tough skins, seeds, and decayed spots of fruits and vegetables, and bones of meat are considered inedible parts because they are not suitable for human consumption.
Inert Relatively inactive.
Ingest To eat or take in through the mouth.
Inorganic Chemical compounds that do not contain carbon.
Intake Substances or amounts of substances which are taken in by the body, e.g., the intake of food.
Intestinal juices The digestive juices secreted by the intestinal walls (in contrast to gastric juices secreted by the stomach walls) and pancreatic juices secreted by the pancreas. The intestinal juices contain enzymes, which complete the final stages of digestion of protein, fat and carbohydrate.
Intestinal tract The entire intestines, both small and large.
Irradiation Treatment with ultraviolet rays from sunlight or an artificial source; treatment with X-rays or other radioactive agent.
IU The abbreviation for International Units, the measure of the potency of a vitamin.
Labile Easily destroyed.
Lactic acid A compound formed in the chemical metabolic processes which accompany muscular activity; also a substance formed by the fermentation of lactose, the sugar in milk.

Lactose A sugar that occurs in milk. It is a white, crystalline sugar that is less soluble and less sweet than ordinary cane sugar (sucrose).

Linoleic acid One of the digestion products from certain fats, which is essential to body tissues. See polyunsaturated fatty acids.

Lipids A broad term for fats and fat-like substances; characterized by the presence of one or more fatty acids. Lipids include fats, cholesterol, lecithins, phospholipids, and similar substances, which do not mix readily with water.

Lymph A yellowish liquid that contains corpuscles and is present in the lymphatic vessels or channels of the body.

Malformation A deformity; an abnormal development or formation of a part of the body.

Matrix The intercellular framework of a tissue.

Maturation The process of coming to full development, maturity, or adulthood.

Meat The flesh of animals used as food. Meat contains proteins, fats, minerals, vitamins, and water. The most common meats used as food are beef, veal, lamb, and pork. Poultry and fish are sometimes included with the foods classified as meat.

Metabolic Refers to metabolism.

Metabolism The sum of the chemical changes that go on in the body as food is made into body tissues, energy is produced, and body tissue is broken down. There are two parts to body metabolism: anabolism—is constructive and includes building, maintaining, and repairing tissue; catabolism—is destructive and includes changing or breaking down tissue or other materials in the body into simple substances for producing energy and for excretion.

Microbiological Pertaining to microorganisms—that is, microscopic plants or animals. Refers usually to a method by which certain microorganisms are used to determine the amounts of a particular nutrient, like a vitamin or an amino acid, in a food. Such assays are possible because these microorganisms must have these vitamins and amino acids in order to grow. These determinations are called microbiological assays or analyses.

Microorganisms Very small living beings. Bacteria, yeasts, and molds are microorganisms found in foods.

Miscible Capable of being easily mixed. For example, corn syrups are miscible in water; fats cannot be mixed with water but are partly miscible in alcohol and are completely miscible in ether. If the end product is a solution, the products are soluble.

Moisture content The amount of water in a substance.

Molecule A chemical combination of two or more atoms that form a specific substance. For example, the combination of an atom of sodium and an atom of chlorine makes a molecule of sodium chloride, or table salt. This is a comparatively simple molecule. There are also large, complex molecules, such as hemoglobin. Proteins and starches are examples of even larger and very complex molecules containing many atoms.

Morbidity Has the same meaning as sickness. The term is used to indicate the extent of illness in a population as contrasted to mortality or deaths.

Mucosa The mucous membrane that lines the passages and cavities of the body, as in the gastrointestinal tract.

Musculature The muscular apparatus of the body or any part of it.

Neural Refers to nerves or nervous tissue.

Nitrogen A chemical element essential to life. Plants can use some nitrogen compounds direct from the soil and nitrogen-fixing bacteria can use nitrogen directly from the air, but animals must have their nitrogen supplied by foods containing protein.

Nitrogenous A substance containing nitrogen is referred to as nitrogenous. Proteins contain nitrogen, as do the chemical components of proteins—amino acids. Protein-decomposition products containing nitrogen are called nitrogenous extractives. They are found in well-ripened meat and contribute to the flavor of meat.

NRC An abbreviation for National Research Council; usually used when referring to the recommended dietary allowances.

Nutrient A chemical compound with specific functions in the nourishment of the body, such as tryptophan, an amino acid; thiamine, a vitamin; or calcium, a mineral. The body obtains about 50 different nutrients from food.

Nutritionist A professionally trained person who applies the science of nutrition and related subjects in research, teaching, or advisory services.

Obese Excessive overweight due to the presence of a surplus of body fat.

Organic A large group of chemical compounds that contain carbon.

Ossification The process of forming bone. Cartilage is made into bone by the process

of ossification. The minerals, calcium and phosphorus are deposited in the cartilage, changing it into bone.

Ossify To change into bone or bony substance.

Oxidation The removal of electrons, in the most general sense; may also mean the combining with oxygen or the removal of hydrogen.

Oxidative Refers to the processes of oxidation.

Oxygen One of the most plentiful chemical elements. Oxygen makes up 65% of the human body. When other chemical substances combine with oxygen, energy is released.

Palatability The quality characteristics (such as color, flavor, and texture) of a food product that make an impression on the organs of touch, taste, smell, or sight and have significance in determining the acceptability of the food product to the user.

Pancreas A glandular organ extending across the upper abdomen close to the liver. It secretes into the intestinal tract digestive juices containing enzymes to act upon protein, fat, and carbohydrate. It also secretes directly into the blood the hormone insulin, which is essential for one stage in the oxidation of sugar to carbon dioxide and water. Adjective: *pancreatic*.

Parathyroid Four small glands in the neck situated beside the thyroid gland. They secrete the hormone that affects calcium metabolism.

Parts per million A way of expressing amounts, especially of trace minerals in diets of foods. Examples of how small a part per million is: It is equal to 1 lb in 500 tons, 1 in. in about 16 miles, or 1 cent in $10,000.

Pathology The branch of medicine that deals with the special nature of disease.

Peroxidase An enzyme that speeds up oxidative changes in certain plant constituents.

Phospholipids Fat-like substances containing phosphorus and nitrogen, along with fatty acids and cholesterol. Phospholipids are abundant in brain and nerve tissues, in egg yolk, and in some plant sterols, as in soybean lecithin.

Phosphorus A mineral element necessary for the formation of bone and essential in the blood and soft tissues of the body.

Physiological Refers to the science of physiology, which deals with functions of living organisms or their parts.

Pigment Any of the coloring materials in the cells and tissues of plants and animals. In fruit and vegetables, the green pigment is chlorophyll; orange to red pigments are carotenoids; red to blue colors are anthocyanins; light-yellow pigments are flavones and flavonols. In meat, the chief pigment producing the pink or red color is myoglobin.

Pituitary gland A gland, in the lower part of the brain, which produces a number of hormones. These hormones regulate the growth of all body tissues and regulate the development and action of other endocrine glands such as the thyroid, pancreas, and adrenal glands.

Plasma The colorless fluid portion of the blood in which the cells are suspended.

Polyunsaturated fatty acids A class of fatty acids that have more than 1 unsaturated linkage in the chain, each lacking 2 hydrogens. Saturated fatty acids have all the hydrogens the carbon chain can hold. Monounsaturated fatty acids have only one unsaturated linkage. Although there are many kinds of polyunsaturated fatty acids, linoleic appears to be the only one which the body cannot synthesize and so must receive from food sources.

Pregnancy The condition of having a developing embryo in the body; the state of being with child.

Progesterone A sex hormone secreted by the corpus luteum in the ovary.

Protein One of a group of complex organic compounds that contain nitrogen, carbon, hydrogen, and oxygen and are essential for life and growth. They are formed by various combinations of different amino acids.

Provitamin Any of a number of substances, called carotenes, that occur in nature and can be converted into vitamin A in the body.

Putrefaction The decomposition of proteins by microorganisms under anaerobic conditions, resulting in the production of incompletely oxidized compounds, some of which are foul-smelling.

Pyridoxine One of the B vitamins, commonly designated as vitamin B_6. Strictly speaking, vitamin B_6, includes a group of three vitamins of nutritional interest—pyridoxine, pyridoxamine and pyridoxal.

Radical In chemistry, a group of elements joined in a set formation, which appears as a unit in a series of compounds or participates without decomposition in chemical re-

Small Pellets PELLETS with maximum cross section diameter of 13/64 in.
Textured Feed Refers to pellets and/or crumbles in this text.

Feed Classifications

Complete Feed A complete balanced ration for fowl, animal, or fish. Complete feeds are capable of sustaining life, growth, and/or production without any additional feed being consumed except for water.

Concentrates A fortified *supplement* feed which requires the addition of other feed ingredients to form a complete balanced ration for animal, fowl, or fish. Concentrate feeds are capable of sustaining life, but generally require the addition of other feed ingredients to obtain or sustain maximum production.

Mash Feeds A mixture of nonprocessed and/or individually processed ingredients or combinations of both.

Meal Feeds A ground ingredient, or ingredient otherwise reduced in particle size, or sometimes referred to as combinations of ground ingredients.

Scratch Feeds A mixture consisting entirely of whole or individually prepared grains or a combination of both.

Supplements (Feeding) A feed ingredient or mixture which requires the addition of other feed ingredients to form a complete balanced ration for animal, fowl, or fish. Supplement feed may be capable of sustaining life, growth, and production, but generally only when other feed requirements are met by additional feed ingredients.

Feed Processing Terms

Aspirating Separating materials by use of air
Cleaning Removing foreign material by such methods as scalping, aspirating, magnetic separation, or other methods.
Drying The removal of moisture from ingredients by thermal means
Grading Separating (frequently applied.)
Magnetic Separating Removing ferrous material by magnets
Scalping Removing larger material by passing product through a screen.
Separating Classification of ingredient particles by size, shape, and/or density.

Particle Reduction

Clipping Removing ends of whole grain
Cooking Using heat in the presence of moisture to alter chemical and physical characteristics.
Cracking The reduction of particle size by a combined breakup and crushing action.
Crimping A rolling process using corrugated rolls. Usually entails steaming or conditioning before rolling
Cutting The reduction of ingredient particle size by severing, using edges or knives.
Dehulling The removal of the outer covering from intact grains or seeds.
Dressing The process of breaking or screening off of lumps from ingredients or finished feed to obtain uniformity of texture.
Flaking A rolling process using smooth rolls (usually entails steaming or conditioning before rolling).
Grinding The reduction of particle size by impact, shearing, or attrition.
Mixing Agitating feeds or ingredients until the dispersion reaches the specific degree of uniformity.
Premixing The preliminary blending of ingredients used at low levels with or without diluents (carriers).
Proportioning Measuring amounts of various ingredients for a mix by gravimetric or volumetric means.
Rolling Changing the shape and/or size of ingredients by rolling or compressing between rolls.
Scalping A form of dressing done by screening.
Steaming Treating ingredients with steam to alter physical and/or chemical properties.
Tempering or Conditioning Achieving predetermined uniform moisture and/or temperature of ingredients.

Pelleting

Conditioning Achieving predetermined moisture and/or temperature of ingredients or mixture of ingredients prior to pelleting.
Cooling Reducing temperature of pellets by air movement.
Crumbling Reducing pellets to granular form.
Pelleting Agglomerating individual ingredients or mixtures by compacting and forcing through die openings.
Sizing Classification of pellets or crumbles by particle size.

Special Ingredient Classifications

Additive Feed additive refers to any substance which becomes a component of or affects the characteristics of a feed or food if such substance is not generally recognized, among experts qualified by scientific training and experience to evaluate its safety, as having been adequately shown through scientific procedures to be safe under the conditions of its intended use (as defined by Food and Drug Administration).
Microingredients Added vitamins, trace minerals, antibiotics, drugs, and other materials used in minute amounts.
Premix A combination of one or more microingredients with diluents.

Special Process

Blocking Agglomerating individual ingredients or mixtures into a large mass by means of reciprocating piston machinery.
Expanding Agglomerating mash feeds by gelatinizing the cereal portion and then extruding and expanding to form expanded pellets.
Kibbling (1) Cracking or crushing of a baked dough to form kibbled feed; or (2) the extrusion of cooked feed mixtures and subsequent cooling and drying to form kibbled feed.
Wafering Agglomerating feeds of fibrous basic ingredients, by compressing into a finished form usually having a diameter or cross section measurement greater than its length.

PART 3—FEED TERMS

Ammoniated (Ammoniating) Combined with or impregnated with ammonia or an ammonium compound.
Antibiotics A drug usually synthesized by a living microorganism and in proper concentration capable of inhibiting the growth of or destroying other microorganisms.
Aspirated (Aspirating) Having removed chaff, dust, or other light materials by use of air.
Bagasse The crushed remains of sugar cane after removal of the juice.
Balanced feed A feed having all known required nutrients in proper amount and proportion based upon recommendations of recognized authorities in the field of animal nutrition, such as the National Research Council. The species for which it is intended and conditions of growth and development should be specified.
Beans Seeds of leguminous plants, especially of the genera *Phaseolus*, *Dalichos*, and *Vigna*.
Biscuits Shaped and baked dough.
Blending To mingle or combine two or more ingredients or feed. It does not imply a uniformity of dispersion.
Blocked (Blocking) Having agglomerated individual ingredients or mixtures into a large mass.
Blocks Agglomerated feed compressed into a solid mass cohesive enough to hold its form and usually weighing over 2 lb.
Blood Red vascular fluid of animals.
Bolted (Bolting) Separated by means of a bolting cloth, as bran from flour.
Bone Skeletal parts of vertebrates.

Bran Pericarp of grain.
Buttermilk Liquid residue from churning cream.
By-product Product produced in addition to the principal product.
Cake The mass resulting from the pressing of seeds, meat, or fish in order to remove oils, fats, or other liquids.
Calcined (Calcining) Treated at high temperature in presence of air.
Cannery waste Residue suitable for feeding from a canning process.
Carcass meat trimmings Clean flesh obtained from slaughtered animals. It is limited to striate, skeletal, and cardiac muscles, but may include the accompanying and overlaying fat and the portions of skin, sinew, nerve, and blood vessels which normally accompany the flesh.
Carcass residue, mammals Residues from animal tissues exclusive of hair, hoofs, horns, and contents of the digestive tract.
Carriers An edible material to which ingredients are added to facilitate the uniform incorporation of the latter into feeds.
Chaff Glumes, husks, or other seed covering combined with other plant parts separated from seed in threshing or processing.
Charcoal Dark-colored porous form of carbon made from the organic parts of vegetable or animal substances by their incomplete combustion.
Chipped (Chipping) Cut or broken into fragments, also meaning prepared into small, thin slices.
Chopped (Chopping) Reduced in particle size by cutting with knives or other sharp instruments.
Cleaned (Cleaning) Removal of material by such methods as scalping, aspirating, magnetic separation, or by other method.
Cleanings Chaff, weed seeds, dust, and other foreign matter removed from cereal grains.
Clipped (Clipping) Removal of the end of whole grain.
Coagulated (Coagulating) Curdled, clotted, or congealed, usually by the action of a coagulant.
Cobs The fibrous inner portion of the ear of maize from which the kernels have been removed.
Commercial feed See Uniform State Feed Bill, Section 3(d)
Complete feed A nutritionally adequate feed for animals other than man, is compounded by specific formula to be fed as the sole ration and is capable of maintaining life and/or promoting production without any additional substance being consumed except water.
Concentrate A feed used with another to improve the nutritive balance of the total and intended to be further diluted and mixed to produce a supplement or a complete feed.
Condensed (Condensing) Reduced to denser form by removal of moisture.
Conditioned (Conditioning) Having achieved predetermined moisture characteristics and/or temperature of ingredients or a mixture of ingredients prior to further processing.
Cooked (Cooking) Heated in the presence of moisture of alter chemical and/or physical characteristics or to sterilize
Cooled (Cooling) Temperature reduced by air movement, usually accompanied by a simultaneous drying action
Cracked (Cracking) Particle size reduced by a combined breaking and crushing action.
Cracklings Residue after removal of fat from adipose tissue or skin of animals by dry heat.
Crimped (Crimping) Rolled by use of corrugated rollers It may entail tempering or conditioning and cooling
Crumbled (Crumbling) Pellets reduced to granular form
Crumbles Pelleted feed reduced to granular form
Crushed (Crushing) See *rolled (rolling)*.
Cubes See *pellets*
Cubes, range See *pellets* and *range cubes*.
Cull Material rejected as inferior in the process of grading or separating.
Culture Nutrient medium inoculated with specific microorganisms which may be in a live or dormant condition.
Cultured (Culturing) Biological material multiplied or produced in a nutrient media.
Cut (Cutting) See *chopped (chopping)*.
D-activated (D-activating) Plant or animal sterol fractions which have been Vitamin D activated by ultraviolet light or by other means.

Defluorinated (Defluorinating) Fluorine removed.
Dehulled (Dehulling) Having removed the outer covering from grains or other seeds.
Dehydrated (Dehydrating) Having been freed of moisture by thermal means.
Diet Feed ingredient or mixture of ingredients including water that is consumed by animals.
Digested (Digesting) Subjected to prolonged heat and moisture, or to chemicals or enzymes with a resultant change or decomposition of the physical or chemical nature.
Diluent An edible substance used to mix with and reduce the concentration of nutrients and/or additives to make them more acceptable to animals, safer to use, or more capable of being mixed uniformly in a feed. (It may also be a carrier.)
Distillation solubles Stillage filtrate.
Dressed (Dressing) Made uniform in texture by breaking or screening of lumps from feed and the application of liquids.
Dried (Drying) Materials from which water or other liquid has been removed.
Drugs A substance (1) intended or represented for the cure, mitigation, treatment or prevention of disease of man or other animals, or (2) intended to affect the structure of any function of the body of man or other animal. (Under study by special committee.)
Dry-rendered (Dry-rendering) Residues of animal tissues cooked in open steam-jacketed vessels until the water has evaporated. Fat is removed by draining and pressing the solid residue.
Dust Fine, dry, pulverized particles of matter usually resulting from the cleaning or grinding of grain.
Ears Entire fruiting heads of *Zea mays* including the cob and grain.
Egg albumin Whites of eggs of poultry.
Emulsifier A subtance capable of holding in suspension two or more liquids which do not normally dissolve in each other.
Endosperm Starchy portion of seed.
Evaporated (Evaporating) Reduced to a denser form; concentrated as by evaporation or distillation.
Expanded (Expanding) Subjected to moisture, pressure, and temperature to gelatinize the starch portion. When extruded, its volume is increased, due to abrupt reduction in pressure.
Extracted, mechanical Having removed fat or oil from materials by organic solvents. Similar terms: expeller extracted, hydraulic extracted, "old process."
Extracted, solvent Having removed fat or oil from materials by organic solvents. Similar term: "new process."
Fat A substance consisting chiefly of glycerides of fatty acids insoluble in water but soluble in certain organic solvents.
Fatty acids Aliphatic monobasic acids containing only the elements carbon, hydrogen, and oxygen.
Feathers The light, horny epidermal outgrowths that form the external covering of birds.
Feed(s) Edible material(s) which are consumed by animals and contribute energy and/or nutrients to the animal's diet. (Usually refers to animals rather than man.)
Feed grade Suitable for animal consumption.
Feed mixture See *formula feed.*
Feedstuff (See feed(s)
Fermented (Fermenting) Acted upon by yeasts, molds, or bacteria in a controlled aerobic or anaerobic process in the manufacture of such products as alcohols, acids, vitamins of the B-complex group, and antibiotics.
Fines (in crumbles or pellets) Any material which will pass through a screen whose openings are immediately smaller than the specified minimum crumble size or pellet diameter.
Flaked (Flaking) See *rolled.*
Flakes An ingredient rolled or cut into flat pieces with or without prior steam conditioning.
Flour Soft, finely ground and bolted meal obtained from the milling of cereal grains, other seeds, or products. It consists essentially of the starch and gluten of the endosperm.
Fodder The green or cured plant, containing all the ears or seed heads, if any, grown primarily for forage. (It has been applied more specifically to corn and sorghum.)
Food(s) When used in reference to animals, is synonymous with feed(s). See feed(s).
Formula feed Two or more ingredients proportioned, mixed, and processed according to specifications.

Free choice A feeding system by which animals are given unlimited access to the separate components or groups of components constituting the diet.
Fused (Fusing) Melted by heat.
Gelatinized (Gelatinizing) Having had the starch granules completely ruptured; brought about by a combination of moisture, heat, and pressure, and in some instances by mechanical shear.
Germ The embryo found in seeds and frequently separated from the starch endosperm during milling.
Gluten The tough, viscid, nitrogenous substance remaining when the flour or wheat or other grain is washed to remove the starch.
Gossypol A phenolic pigment in cottonseed that is toxic to some animals.
Grain Seed from cereal plants.
Grease Animal fats with a titer below 104° F.
Grits Coarsely ground grain from which the bran and germ have been removed, usually screened to uniform particle size.
Groats Grain from which the hulls have been removed.
Ground grinding Reduced in particle size by impact, shearing, or attrition.
Hay The aerial portion of grass or herbage especially cut and cured for animal feeding.
Heads The seed or grain-containing portions of a plant.
Heat-processed (Heat-processing) Subjected to a method of preparation involving the use of elevated temperatures, with or without pressure.
Heat-rendered (Heat rendering) Melted, extracted, or clarified through use of heat. Usually, water and fat are removed.
Homogenized (Homogenizing) Fat particles broken down to evenly distributed small globules and allow them to be emulsified for long periods of time.
Hulls Outer covering of grain or other seed.
Husks Leaves enveloping an ear of maize; or the outer coverings of kernels or seeds, especially when dry and membranous.
Hydrolyzed (Hydrolyzing) Complex molecules having been split to simpler units by chemical reaction with water, usually by catalysis.
Ingredient Any component in a mixture.
Irradiated (Irradiating) Treated, prepared or altered by exposure to a specific radiation.
Juice The aqueous substance obtainable from biological tissue by pressing or filtering with or without addition of water.
Kernel A whole grain. For other species, dehulled seed.
Kibbled (Kibbling) Cracked or crushed, baked dough, or extruded feed that has been cooked prior to or during the extrusion process.
Lard Rendered fat of swine.
Leaves Lateral outgrowth of stems of plants
Lecithin A specific phospholipid. The principal constituent of crude phosphatides derived from oil-bearing seeds.
Liver The hepatic gland.
Malt Sprouted and steamed whole grain from which the radicle has been removed.
Malted (Malting) Converted into malt or treated with malt or malt extract.
Mash An ingredient which has been ground or otherwise reduced in particle size.
Microingredients Vitamins, minerals, antibiotics, drugs and other materials normally required in low concentrations.
Middlings A by-product of flour milling comprising several grades of granular particles containing different proportions of endosperm, bran, germ, and each of which contains different levels of crude fiber
Milk Total lacteal secretion from the mammary gland.
Mill by-product A secondary product obtained in addition to the principal product in milling practice.
Mill Run The state in which a material comes from the mill, ungraded and usually uninspected.
Mixing To combine by agitation two or more materials to a specific degree of dispersion.
Molasses The thick, viscous by-product resulting from refined sugar production or the concentrated, partially dehydrated juices from fruits.
Offal, poultry The eviscerated portion of slaughtered poultry such as heads, feet, undeveloped eggs, and intestines, exclusive of feathers.
Oil Liquid fat.
Pearled (Pearling) Dehulled grains reduced by machine brushing into smaller smooth particles.

Peel See skin.
Pellets Agglomerated feed formed by compacting and forcing through die openings by a mechanical process. Similar terms: pelleted feed, hard pellet.
Pellets, soft Pellets containing a large percentage of liquids requiring immediate dusting and cooling.
Pelleted (Pelleting) Having agglomerated feed by compacted and forced through die openings.
Pomace The solid residue remaining after the extraction of juice or other products from fruits.
Precipitated (Precipitating) Separated from suspension or solution as a result of some chemical or physical change brought about by a chemical reagent, by cold, or by other means.
Premix A uniform mixture of one or more microingredients with diluent and/or carrier. Premixes are used to facilitate uniform dispersion of the microingredients in a larger mix.
Premixing The preliminary mixing of ingredients with diluents and/or carriers.
Pressed (Pressing) Compacted or molded by pressure; also meaning having fat, oil, or juices extracted under pressure.
Presswater The aqueous extract of fish or meat free from the fats and/or oils. Presswater is the result of hydraulic pressing of the fish or meat followed by separation of the oil either by centrifuging or other means.
Product A substance produced from one or more other substances as a result of chemical or physical change.
Protein Any of a large class of naturally occurring complex combinations of amino acids.
Pulp The solid residue remaining after extraction of juices from the sugar beet root, other roots, or fruits. (See *pomace*.)
Pulverized See *ground* (*grinding*).
Range cake See *cake*.
Range cubes Large pellets designed to be fed on the ground. Similar term: range wafer.
Ration The amount of the total feed or any specified portion of it which is provided to 1 animal over a 24-hr period.
Residue Part remaining after the removal of a portion of its original constituents.
Rolled (Rolling) Having changed the shape and/or size of particles by compressing between rollers. It may entail tempering or conditioning.
Rumen contents Contents of the first two compartments of the stomach of a ruminant.
Scalped (Scalping) Having removed larger material by screening.
Scratch Whole, cracked or coarsely cut grain. Similar terms: scratch grain, scratch feed.
Screened (Screening) Having separated various sized particles by passing over and/or through screens.
Self fed A feeding system where animals have continuous free access to some or all components of a ration, either individually or as mixtures.
Separating Classification of particle by size, shape, and/or density.
Separating, magnetic Removing ferrous material by magnetic attraction.
Shells The hard, fibrous, calcareous covering of a plant or animal product, i.e., nut, egg, or oyster.
Shorts Fine particles of bran, germ, flour, or offal from the tail of the mill from commercial flour milling.
Sizing See *Screening*.
Skin Outer coverings of fruits or seeds, as the rinds, husks, or peels. May also apply to dermal tissue of animals.
Solubles Liquid containing dissolved substances obtained from processing animal or plant materials. It may contain some fine suspended solids.
Spent Exhausted of active or effective properties, i.e., absorbing activity.
Stalk(s) The main stem of an herbaceous plant often with its dependent parts, as leaves, twigs, and fruit.
Starch A white, granular glucose polymer of plant origin.
Steamed (Steaming) Having treated ingredients with steam to alter physical and/or chemical properties. Similar terms: steam cooked, steam rendered, tanked.
Steep-extracting (Steep-extracted) Soaked in water or other liquid (as in the wet milling of corn) to remove soluble materials.
Steepwater Water containing soluble materials extracted by steep-extraction, i.e., by soaking in water or other liquid (as in the wet milling of corn).

Stems The coarse, aerial parts of plants which serve as supporting structures for leaves, buds, and fruit.
Sterol A class of solid cyclic alcohols widely distributed in animal and plant lipides.
Stick See *stickwater, presswater.*
Stickwater, fish The aqueous extract of fish free from the oil. Stickwater contains the aqueous cell solutions of the fish and any water used in processing.
Stickwater, meat The aqueous extract of meat free from the fat. Meat stickwater is the result of the wet rendering of meat products and contains the aqueous cell solution and the soluble glue proteins and the water condensed from steam used in wet rendering.
Stillage The mash from fermentation of grains after removal of alcohol by distillation.
Straw The plant residue remaining after separation of the seeds in threshing; it includes chaff.
Stover The stalks and leaves of corn after the ears, or sorghum after the heads have been harvested.
Supplement A feed used with another to improve the nutrient balance at the total and intended to be: (1) feed undiluted as a supplement to other rations, or, (2) offered free-choice with other parts of the ration separately available; or (3) further diluted and mixed to produce a complete feed
Syrup Concentrated juice of a fruit or plant.
Tallow See *carcass residue.*
Tempered (Tempering) See *conditioned (conditioning).*
Titer A property of fat determined by the solidification point of the fatty acids liberated by hydrolysis.
Trace minerals Mineral nutrients required by animals in small amounts only (measurable in milligrams per pound or smaller units).
Unsaponifiable matter Ether soluble material extractable after complete reaction with strong alkali.
Vines Any plant whose stems require support, or lie on the ground
Viscera All the organs in the great cavity of the body, excluding contents of the intestinal tract.
Vitamins Organic compounds that function as parts of enzyme systems essential for the transformation of energy and the regulation of body metabolism
Wafered (Wafering) Having agglomerated a feed of a fibrous nature by compressing into a form usually having a diameter or cross section measurement greater than its length.
Wafers A form of agglomerated feed based on fibrous ingredients in which the finished form usually has a diameter or cross section measurement greater than its length.
Waste Damaged, defective, or superfluous edible material produced during or left over from a manufacturing or industrial process
Wet-rendered (Wet rendering) Cooked with steam under pressure in closed tanks
Whey The watery part of milk separated from the curd
Whey solids The solids of whey (proteins, fats, lactose, ash, and lactic acid)
Whole pressed (Whole pressing) Having pressed the entire seed to remove oil
Wort The liquid portion of malted grain It is a solution of malt sugar and other water soluble extracts from malted mash

PART 4—U.S. FOOD AND DRUG ADMINISTRATION DEFINITIONS

(1) A "complete feed" is an article intended to be administered as the sole ration to an animal

(2) A "feed additive supplement" is an article for the diet of an animal which contains one or more food additives, and is intended to be

(i) further diluted and mixed to produce a complete feed, or
(ii) fed undiluted as a supplement to other rations; or
(iii) offered free choice with other parts of the ration separately available.

A "feed additive supplement" is safe for the animal and will not produce unsafe residues in the edible products from food-producing animals if fed according to directions.

(3) A "feed additive concentrate" is an article intended to be further diluted to produce a complete feed or a feed additive supplement and is not suitable for offering free choice without dilution. It contains, among other things, one or more additives in amounts, in a suit-

able feed base, such that from 100 to 1,000 lb of concentrate must be diluted to produce 1 ton of a complete feed. A "feed additive concentrate" is unsafe if fed free choice or as a supplement, because of danger to the health of the animal or because of the production of residues in the edible products from food-producing animals in excess of safe levels.

(4) A "feed additive premix" is an article that must be diluted for safe use in a feed additive concentrate, a feed additive supplement, or a complete feed. It contains, among other things, one or more additives in high concentration in a suitable feed base such that up to 100 lb must be diluted to produce 1 ton of a complete feed. A "feed additive premix" contains additives at levels for which safety to the animal has not been demonstrated and/or which may result, when fed undiluted, in residues in the edible products from food-producing animals in excess of the safe levels.

(5) In feeding chickens:

(i) "Broiler chickens" are chickens raised for meat purposes only.

(ii) "Replacement chickens" are chickens being raised for the purpose of egg production.

(iii) "Laying chickens" are chickens producing eggs for food.

(iv) "Breeding chickens" are chickens producing eggs used for hatching.

(6) "Taste" describes the collective sensations of smell, taste, texture, and a multitude of other factors that can contribute to the stimulation that occurs with ingestion of food.

(7) Poultry includes all domesticated birds, such as chickens, ducks, geese, guineas, ostriches, peafowl, pigeons, swans, turkeys, pheasants, quail, partridges, and grouse. Many persons, however, use poultry and chickens interchangeably.

PART 5—TERMS FOR STRUCTURE AND COMPOSITION OF FOODS

Cellular Tissues

Collenchyma Cells with conspicuous thickenings at the angles; walls of cellulose or a modification, not lignified.

Cork Protective tissue of tabular cells in radial rows with suberin as the characteristic constituent of the walls.

Cortex The layer in stems between the epiderm or cork tissue and the central cylinder with the bundle tissues.

Cuticle The membranous coating often covering the epiderm, consisting of cutin, a substance related to lignin.

Emergences Multicellular outgrowths with tissues derived from subepidermal as well as epidermal layers.

Endocarp The innermost layer of the pericarp, often consisting of a dense woody zone.

Epicarp The outer epiderm of the pericarp (fruit coat).

Epiderm The outer and inner tissue layer of organs as for example the spermoderm, also the upper and lower tissue layers of leaves.

Fibro-vascular bundles Compound strands of elongated elements consisting of (1) phloem with sieve tubes, cambiform cells and parenchyma, (2) xylem with pitted, reticulated, spiral and annular vessels, and (3) sheath of vast fibers.

Hairs or Trichomes Unicellular or multicellular outgrowths of the epiderm.

Palisade layer A layer of elongated cells arranged vertical to the surface of the organ.

Parenchyma Thin-walled, isodiametric or moderately elongated cells, with walls usually of cellulose, with or without intercellular spaces at the angles. In *spongy parenchyma*, the intercellular spaces are conspicuous and the contour of the cells is much distorted.

Sclerenchyma Cells with lignified, often strongly pitted walls. Includes stone cells, fibers, and a great variety of other forms.

Stomata The epidermal openings that facilitate assimilation (photosynthesis), respiration, and transpiration.

Water stomata Openings at the ends of nerves through which water is discharged.

Cell Contents

Aleurone grains Protein bodies, present in certain oil seeds, consisting of ground substance containing one or more of the following: (1) crystalloids or protein crystals, (2)

globoids believed to be phosphates with organic salts, and (3) calcium oxalate crystals. Tannins, fats, fatty oils, waxes, volatile or essential oils, and resins do not occur as definite organized bodies, but are recognized by their solubilities or chemical reactions.

Calcium oxalate occurs often as (1) single monoclinic crystals, (2) *crystal rosettes*, (3) raphides or needle-shaped crystals, and (4) crystal sand.

Silica occurs as rounded bodies in the stegmata *of palms and some other plants.*

Inulin Is present in roots and rhizomes. It forms sphaerocrystals with alcohol.

Latex Milky secretions *in tubes in various* leaves, stems, *roots*, and fruits.

Mucilage A general term for gelatinizing substances such as gums and pectins.

Protoplasm The living matter of cells. Among the forms are (1) cytoplasm, which is granular or stringy; (2) cell nucleus, a round or oval body brought out clearly by special stains; and (3) plastids or chromatophores, including chlorophyll grains or chloroplasts, the green bodies of leaves, leucoplasts or starch formers, and *chromoplasts*, the yellow, orange, or red colored bodies of various organs.

Starch Starch has come to be regarded as a *mixture of amylose and* amylopectin, the latter containing H_3PO_4 in its molecule.

Sucrose Is the only soluble carbohydrate usually present in crystalline form, and this only when deposited by evaporation.

PART 6—POULTRY TERMS

Assimilation Digestion, absorption, transporting, and metabolism of nutrients. (Transformation of food into animal tissue.)

Digestible nutrients The difference between the nutrients consumed and those excreted. In the case of the chicken, which excrete the undigested food and the urinary products together, correction is made for the quantity of uric acid present.

Essential amino acids Those required in the diet, because the animal is either unable to synthesize them or unable to synthesize them at a sufficient rate to meet needs for growth or production.

Feedstuff Any material included in a diet because of nutritional properties.

Maintenance requirements That portion of the energy of the food used in the life processes of the animal for keeping the animal warm and for movement of the body.

Mammals Mammals are distinguished by the presence of hair and mammary glands. Birds are distinguished by their covering of feathers.

Metabolism A term applied to all chemical processes occuring within the body contributing to the transformation of matter and energy involved *in growth, muscular activity*, heat production, and the maintenance of vital functions.

Metabolizable energy The energy of the food eaten less the energy of the excrement derived from it, both fecal and urinary, and, in the case of ruminants, in gases produced by fermentation.

Net energy *The metabolizable energy minus that used in utilizing it. It may be used for* maintenance, for the production of fat, flesh, eggs or other animal products, or body movement or work.

Nutrient Any food constituent, or group of food constituents of the same general chemical composition that aids in the support of animal life. These are protein, fat, carbohydrates, vitamins, and minerals. Oxygen and water are sometimes included.

Nutrition The sum of the processes by which an animal or plant absorbs or takes in and utilizes food substances.

Ornithology Ornithology is the study of birds not classified as poultry.

Poultry Used to designate those species of birds which render man an economic service and *reproduce* freely under his care. It includes the following: chickens, turkeys, ducks, geese, guineas, pigeons, pheasant, ostriches, pea fowl, and swan.

Poultry concentrate Contains protein, fat, minerals, vitamins, and a *very small amount* of carbohydrate.

Poultry science Poultry Science is the study of principles and practices involved in the production and marketing of poultry and poultry products. It includes breeding, incubation, brooding, housing, feeding, curing of diseases, marketing, and management.

Productive energy The net energy as measured by the *energy stored up as fat and protein* in a growing or fattening animal.

Protein quality Ability of a protein supplement to meet the protein needs of an animal. Is a measure of the distribution (kind and amount) of the required amino acids and their availability.

PART 7—LIST OF POULTRY BREEDERS

Egg Strain Breeders

Arbor Acres Farm, Glastonbury, Conn.
Babcock Poultry Farm, Ithaca, NY.
DeKalb Agricultural Assoc., Sycamore, Ill.
Heisdorf & Nelson Farms, Kirkland, Wash.
Honegger Breeder Hatchery, Forrest, Ill.
Ghostley's Poultry Farm, Anoka, Minn.
Hy-Line Poultry Farm, Des Moines, Iowa
Kimber Farms, Fremont, Calif.
Shaver Poultry Breeding Farm, Galt, Ontario

Meat Strain Breeders

Arbor Acres Farm, Glastonbury, Conn.
Cobb's Pedigreed Chicks, Concord, N.H.
Hubbard Farms, Walpole, N.H.
Pilch Poultry Breeding Farm, Hazardville, Conn.
Charles Vantress Farms, Duluth, Minn.

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